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Lackawanna

Lackawanna Steel Sheet Piling

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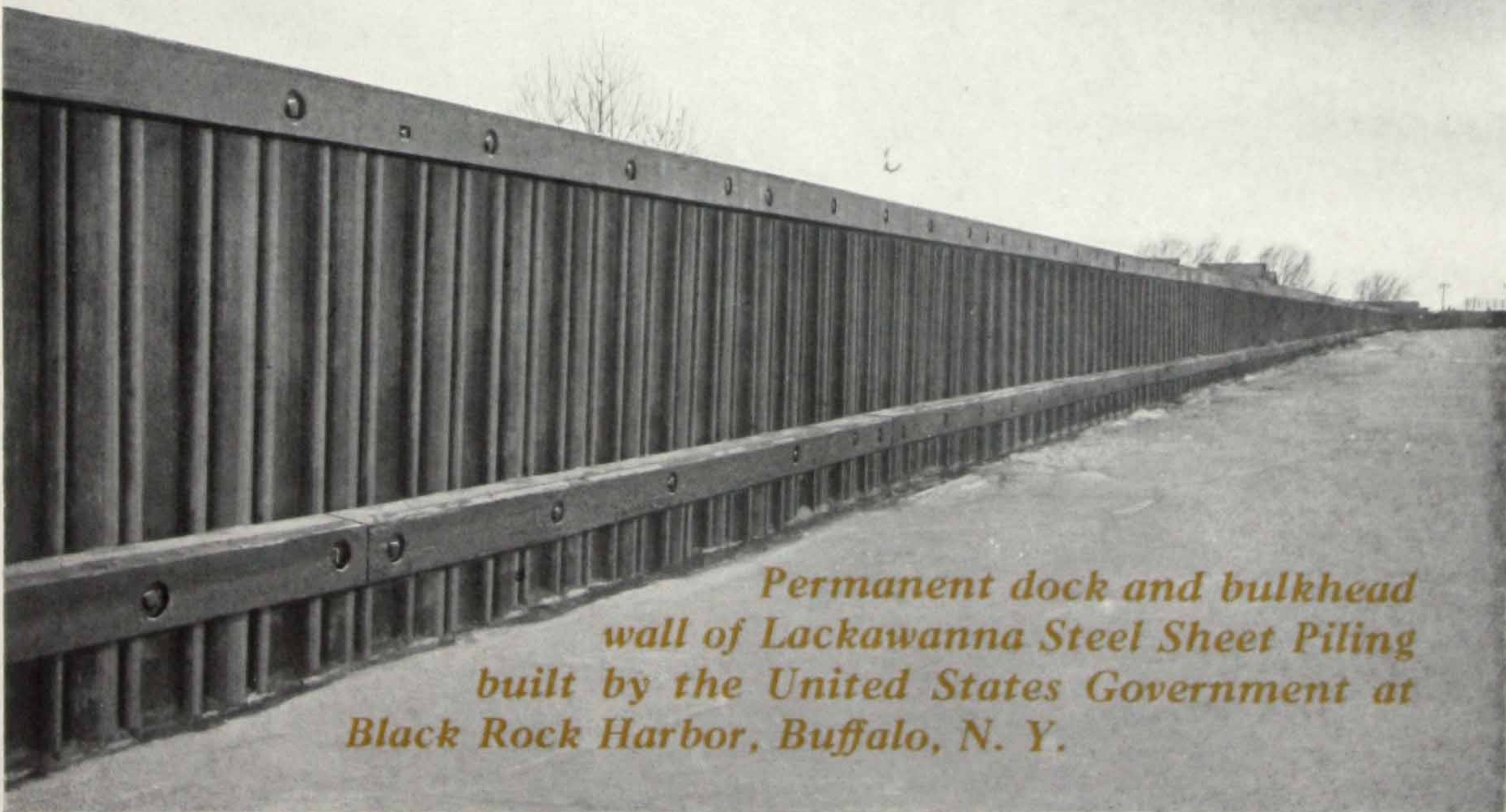
CCA

Bulletin No. 108

Second Edition

Lackawanna Steel Sheet Piling

Arched-Web, Straight-Web
Center-Flange, Protected
and Plate Types



*Permanent dock and bulkhead
wall of Lackawanna Steel Sheet Piling
built by the United States Government at
Black Rock Harbor, Buffalo, N. Y.*



Lackawanna Steel Sheet Piling

Fully protected by United States and foreign patents

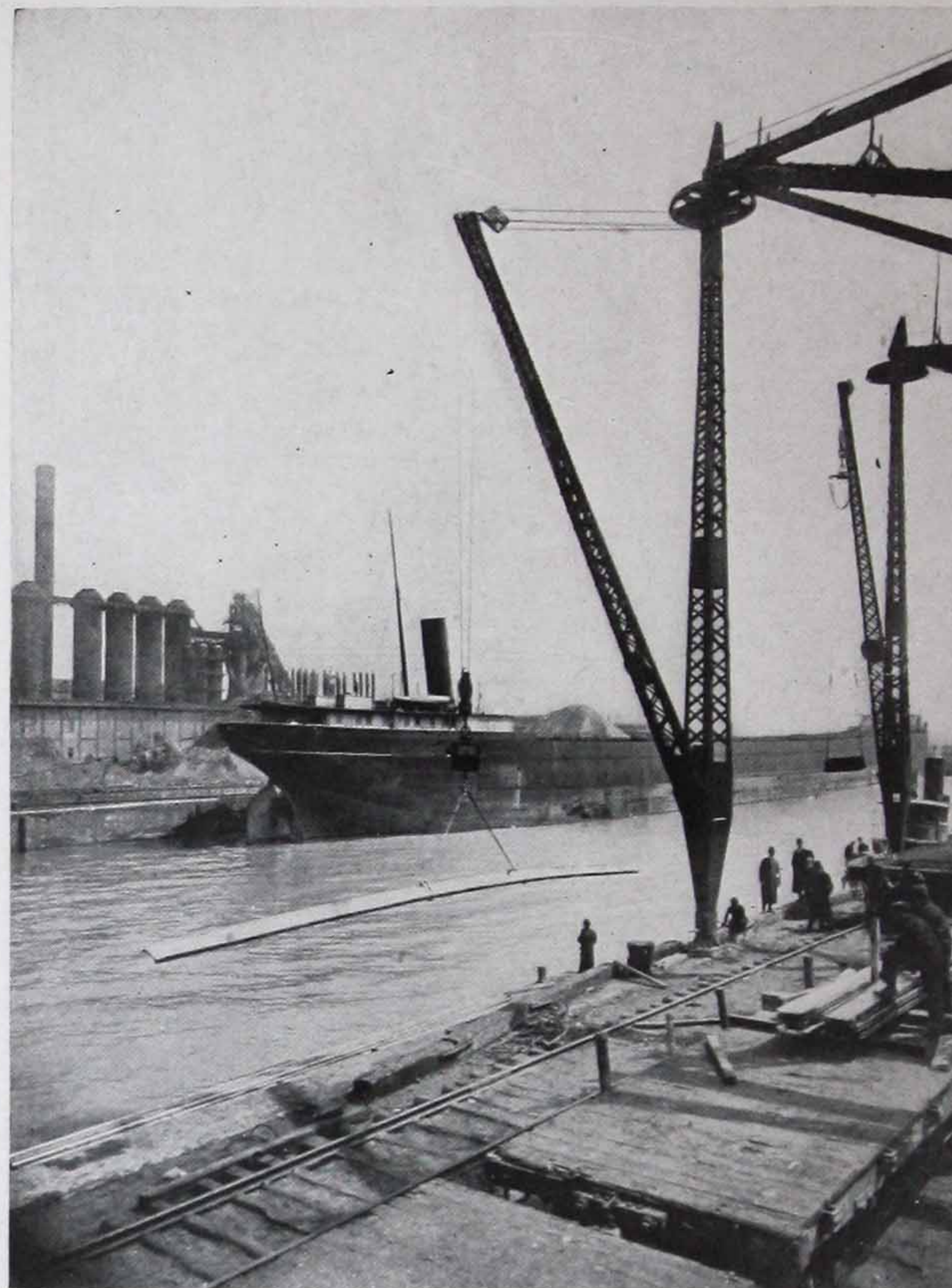
Lackawanna Steel Sheet Piling has thoroughly proven its supremacy in repeated installations by the United States Government (including the two largest cofferdams on record), by foreign governments and by leading engineers and contractors everywhere.

Our types of Steel Sheet Piling have been developed theoretically under the direction of the inventors and an able engineering staff, and have been brought to a high state of mechanical efficiency in mills which have long enjoyed an enviable reputation for the quality of their entire output.

In asking perusal of this and our other bulletins, we wish to impress upon present and prospective customers our eagerness to cooperate in every reasonable way to assure satisfactory service to the purchaser. We maintain a Steel Sheet Piling Engineering Department to furnish reports, suggestions and tentative plans to assist in the correct and economical use of Lackawanna Steel Sheet Piling in the many forms of construction for which it is especially adapted. The experience of our engineers, and the records obtained through connection with a great number of Steel Sheet Piling installations, large and small, are entirely at the service of the purchasers of Lackawanna Steel Sheet Piling.

If we fail in our literature to explain clearly; if you wish to know where Lackawanna Steel Sheet Piling has been used in your vicinity, or under conditions similar to your own; or if you desire help and an estimate on some installation, write us. Our advice, though free, will prove valuable.

New York Buffalo Chicago Cincinnati
Detroit Boston Philadelphia Cleveland
St. Louis Atlanta San Francisco



Delivering Lackawanna Steel Sheet Piling to scows from cars on our docks.

LACKAWANNA STEEL COMPANY

General Sales Office & Works: Lackawanna, N. Y.

Licenses for the manufacture of Lackawanna Steel Sheet Piling: For Great Britain and British Colonies in the Eastern Hemisphere: Cargo-Fleet-Iron Co., Ltd., Middlesbrough, England. For France, Italy, Spain, French Colonies and Protectorates, Italian Colonies and Spanish Colonies in the Eastern Hemisphere: Cie Des Forges & Aciéries de la Marine et d'Homécourt, Paris, France.

Lackawanna Steel Sheet Piling

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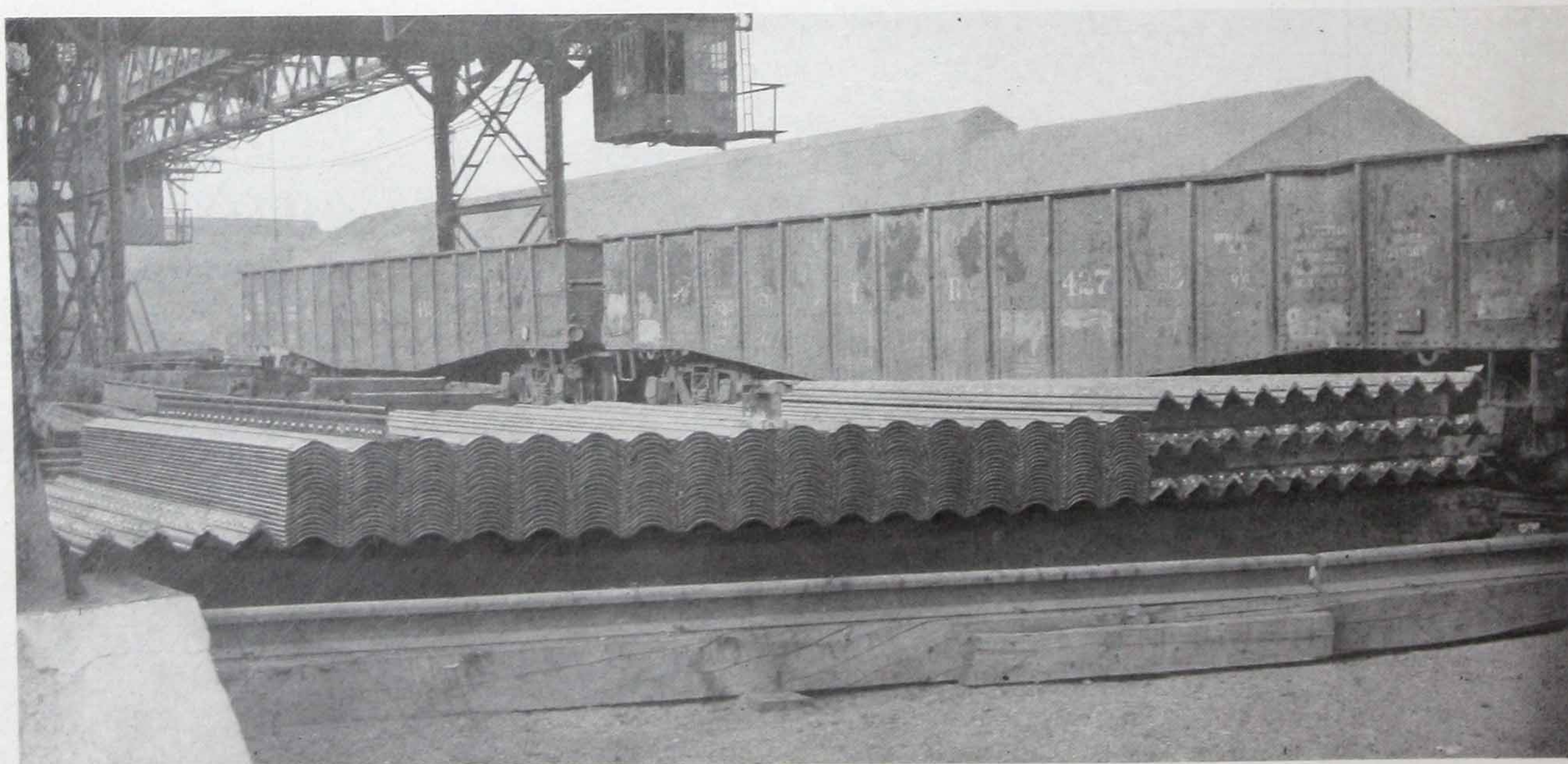
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Lackawanna Steel Company



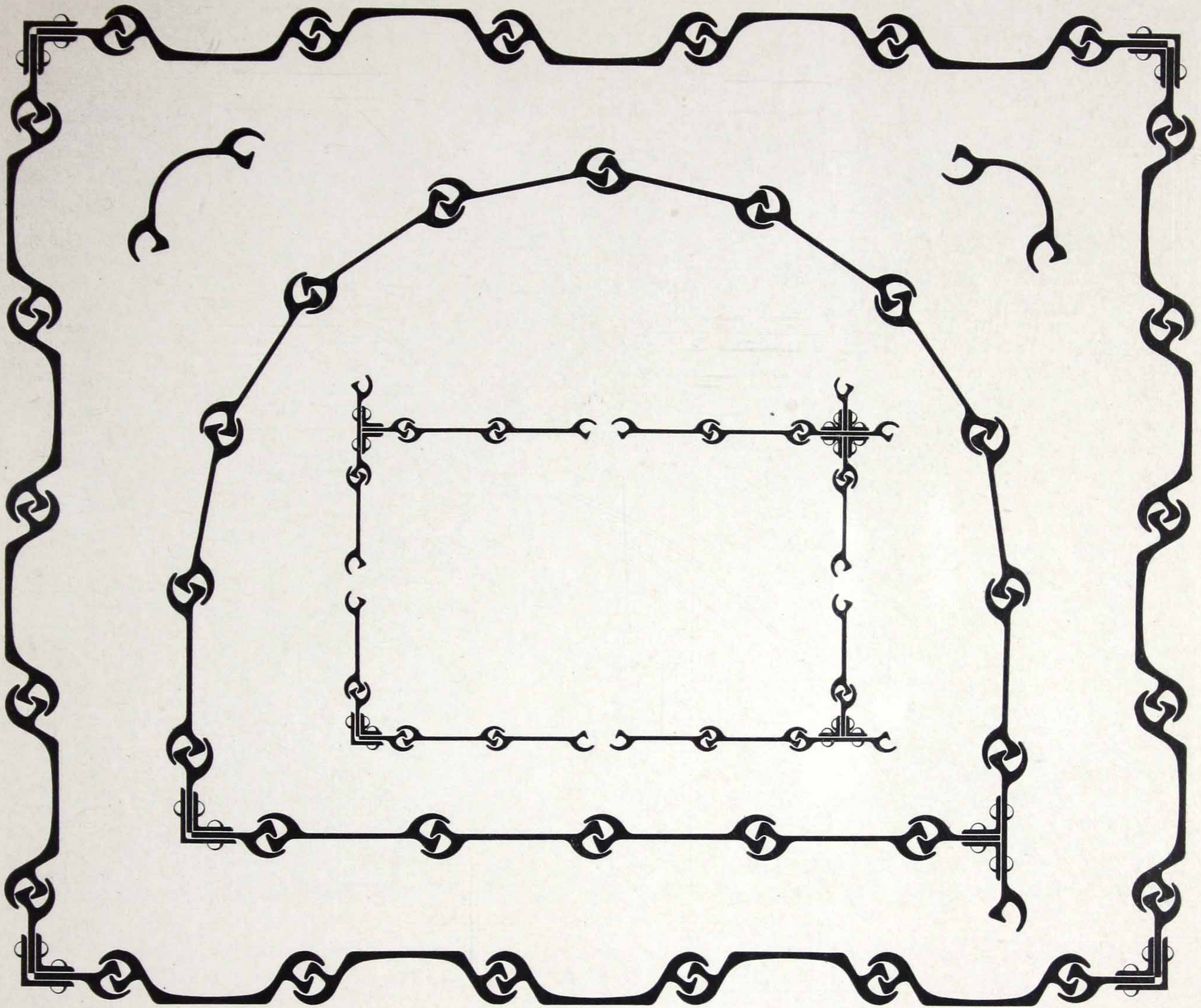
Lackawanna Straight-Web Steel Sheet Piling cut to length, punched for splicing, inspected and in storage at our plant pending shipment.



Lackawanna Plate Sheet Piling ready for shipment. Note extreme uniformity of all sections, and fabricated 90-degree corners.

Straightness is the first essential of any steel sheet piling. These pictures prove the straightness and uniformity of section to which each bar of Lackawanna Steel Sheet Piling is rolled.

Lackawanna Steel Sheet Piling



Typical combinations of circular and straight walls, corners and junctions practical with Lackawanna Steel Sheet Piling.

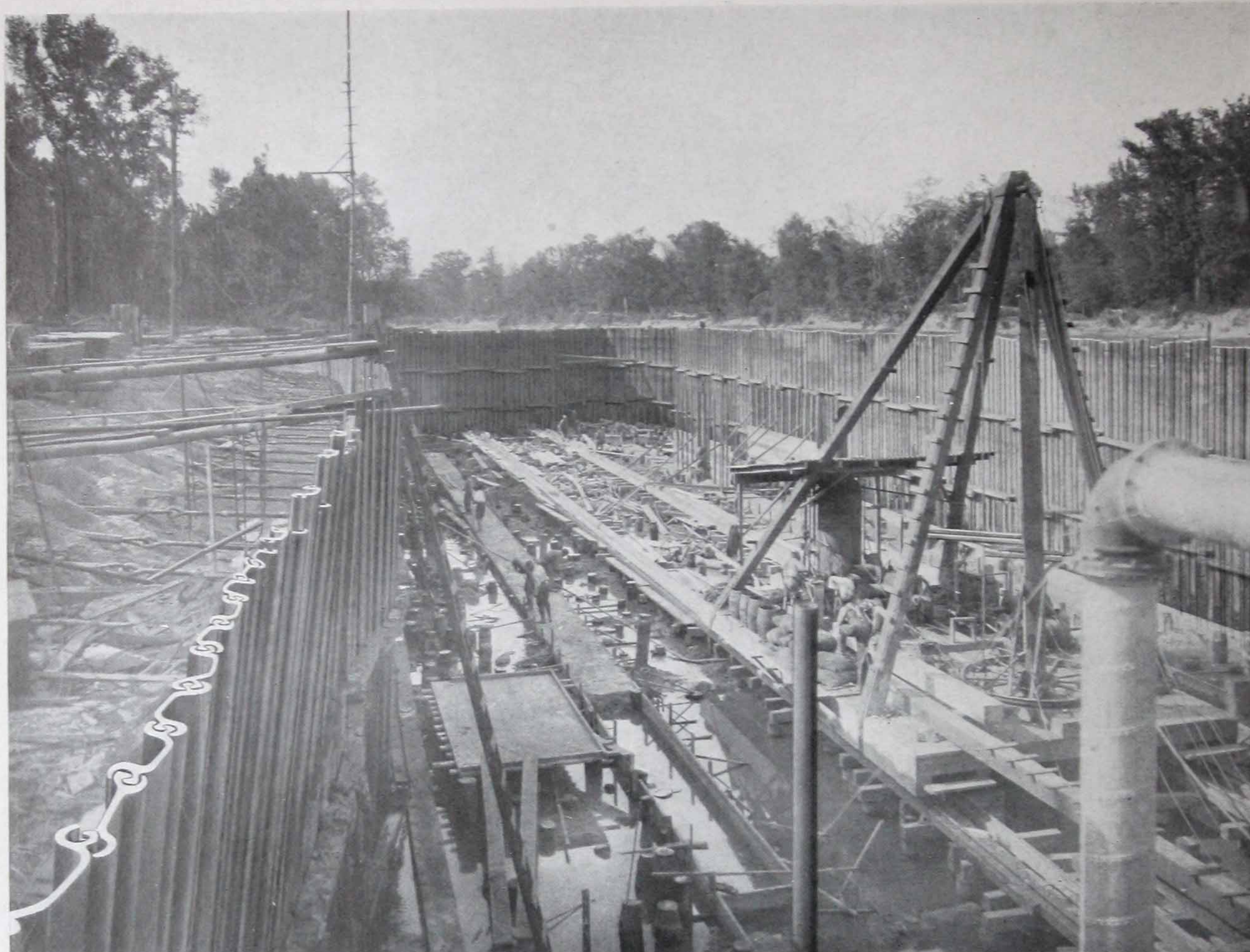
LACKAWANNA Steel Sheet Piling is designed primarily for use:

(1) In temporary construction work where water, earth or other material is to be retained, as in cofferdams, open caissons, retaining walls, foundations of bridges, buildings, etc.

(2) In permanent constructions requiring resistance to water and to the elements and requiring great strength to resist pressure from surrounding or superimposed material or both, as in permanent retaining walls, shaft linings, dams, curtain walls, core walls,

docks, sea walls, bulkheads, locks, irrigation and reclamation work, levees, sumps, pits, pump wells and the like.

The use of steel sheet piling in such work is not novel, but only within the past few years has commercially practical steel sheet piling been developed that would carry the loads, assure the necessary interlocking strength and conform generally to the work to be done both during and after the installation and at low cost. The Lackawanna type of steel sheet piling, as represented by the various sections manufactured, conforms to the requirements of all-around use-



The 313 by 84½-foot Lackawanna Steel Sheet Piling cofferdam built by the United States Government for the construction of the Kings Bluff Lock, on the Cape Fear River, North Carolina.

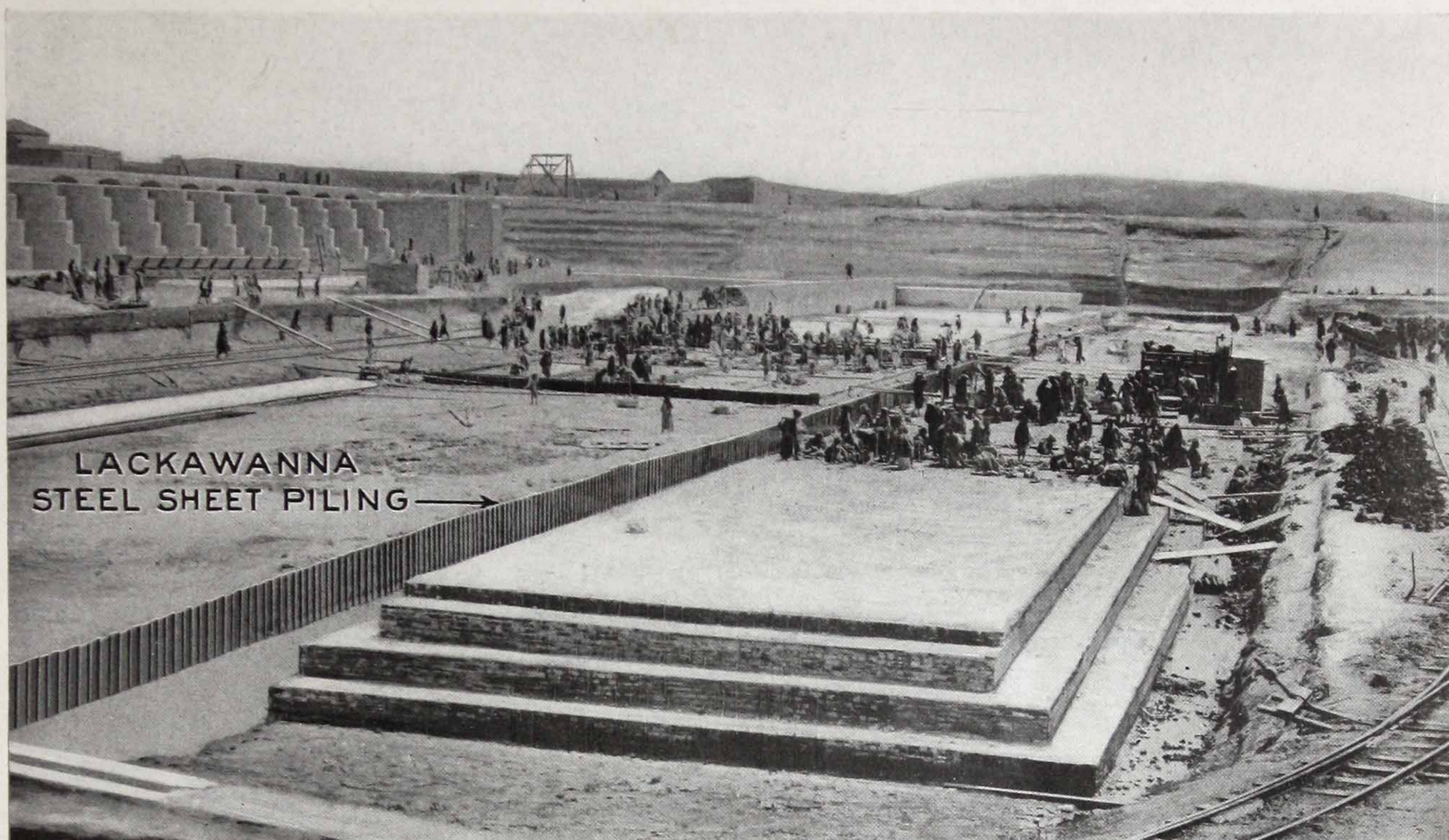
Single walls constructed from 45-foot steel sheet piling lengths formed the sides and up-stream end of this cofferdam, while the down-stream end consisted of pockets of steel sheet piling, filled with dredged material.

A splendid method of tying back the single-wall sides is shown in the above picture. Anchor cables, acting to support each wall near the top, ran back to timber anchors located in the river and on the adjacent bank. These cables were fastened to heavy beam piles located about 8 feet apart at the panel points in the cofferdam walls.

By using in the main walls spliced piling lengths, held together end to end with a bolt splice, maximum economy was combined with efficiency, and recovery of a large percentage of the steel sheet piling was permitted. The splices could therefore be unbolted so that the upper portion of the steel sheet piling composing the walls might be removed when the lock was completed. At the same time a permanent and beneficial steel sheet piling wall could be left in position to protect the lock foundations against scoring from the flow of the river.

A centrifugal pump working at intervals kept the excavation dry here and, as shown, permitted the construction of lock walls 13 feet below river level. The cofferdam successfully withstood a head of 23 feet, having been designed for a head of 26 feet before flooding.

Lackawanna Steel Sheet Piling



The recent dedication, by the Turkish Governor-General of Bagdad, of the Hindieh Barrage, and the re-entrance of the waters of the Euphrates River into their old channel past Babylon, marks the first step toward the reconstruction of the maze of canals of the pre-Christian era. This is part of the \$16,000,000 project to regulate the Euphrates and Tigris Rivers and supply a new irrigating system, designed to bring Mesopotamia back to its old fame as the granary of the world.

800 Tons of Lackawanna Steel Sheet Piling in 17-foot lengths were driven here under the direction of Sir Wm. Willcocks, the great English Engineer and Adviser to the Turkish Minister of Public Works. The above picture shows the barrage (at the left) and a line of the steel sheet piling driven into a permanent curtain wall to prevent percolation under the foundation work.

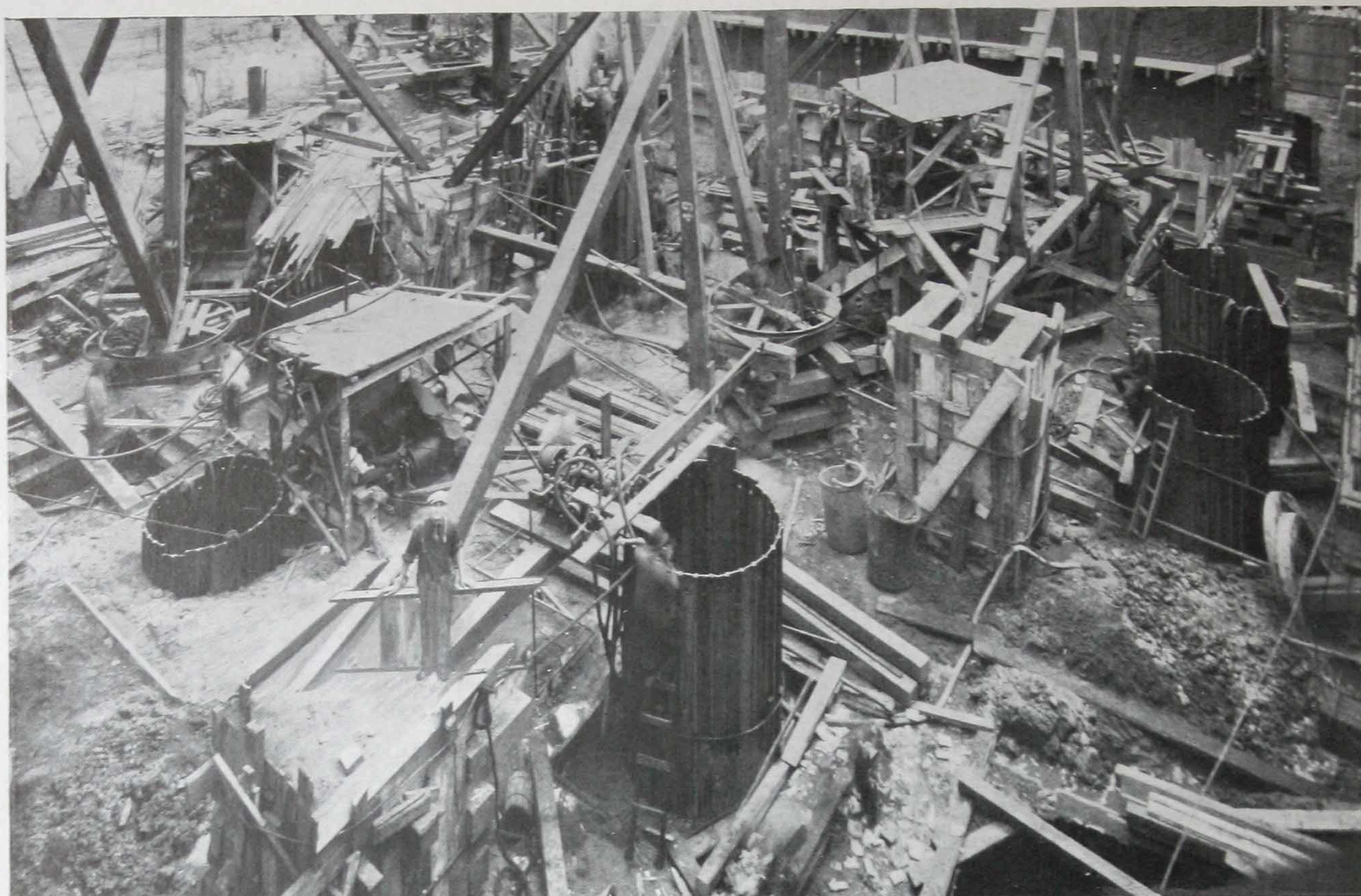
fulness to a greater extent than any other ever offered and can be installed without surplus weight and at the lowest price *per square foot of piling wall in place.*

Characteristics of the Lackawanna Section

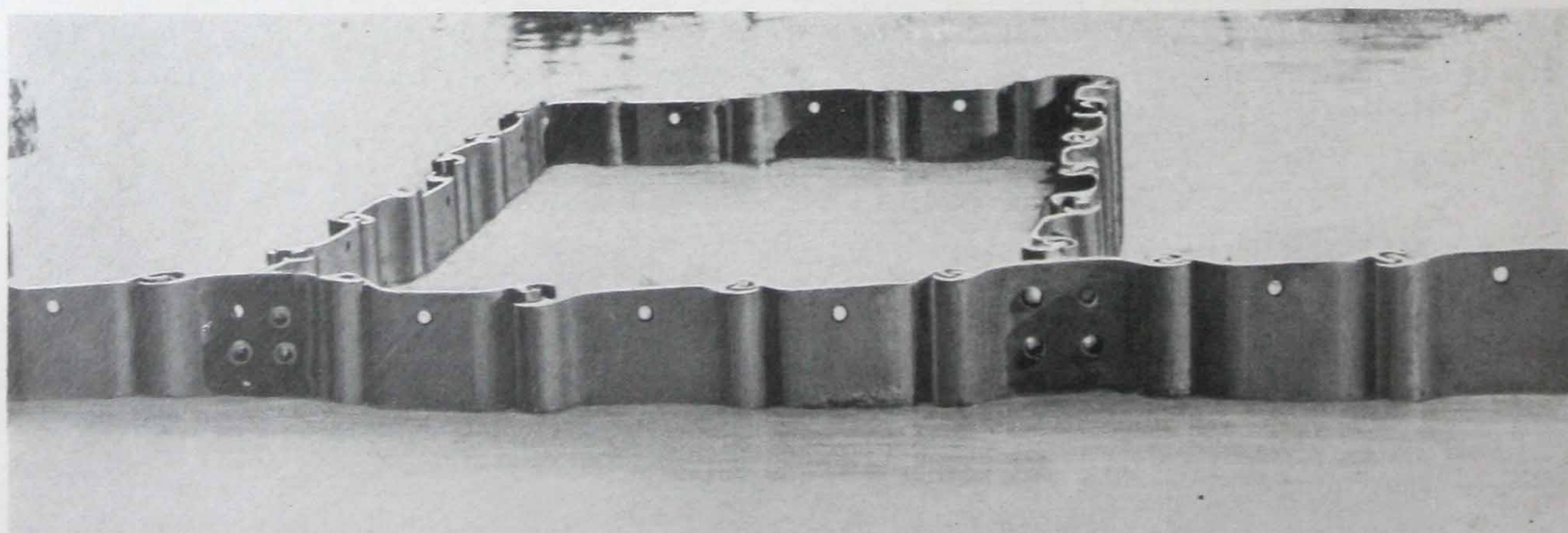
THE standard forms in which Lackawanna Steel Sheet Piling is rolled are described and shown on pages 16, 17, 18 and 20. Each of these sections is entirely integral as it comes from the rolls, simple, strong, solid, durable and easy to drive. No fabrication or other assemblage is required to form the interlock, hence there are

no rivets, bolts or parts to loosen or shear off in handling, driving or pulling.

The interlock consists of similar hooks and guards on both edges of the piling section and so shaped that the interlocked joint formed between adjacent piles is flexible through an equal arc of motion on each side of the center plane of the piling section. The hooks of adjacent sections engage to offer the greatest resistance to longitudinal displacement while the guards overlap and engage the outer surface of the hooks on the adjacent sections, thus preventing lateral displacement and co-operating to prevent longitudinal displacement. The joint can be disengaged only by withdrawing one pile. There are three lines

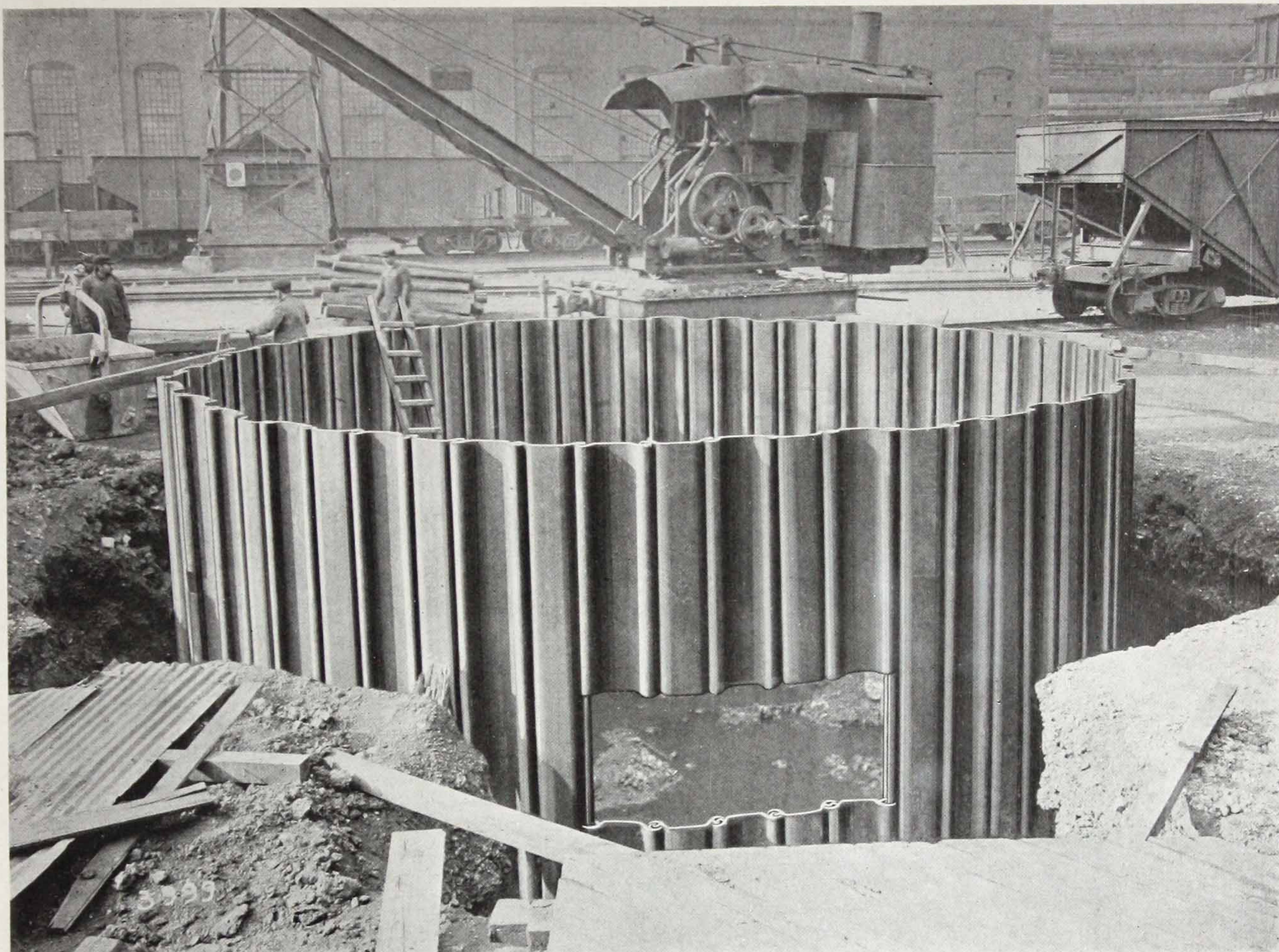


Circular and oval open caissons of Lackawanna Steel Sheet Piling for foundation piers of the 12-story Kinney Building, Newark, N. J. This piling in 25 and 35-foot lengths, penetrated cemented gravel and hard boulders, yet was subsequently withdrawn and found to be in splendid condition for re-use on other work.



The above pocket, forming a pump well, is driven with 30-foot lengths of Lackawanna Arched-Web Steel Sheet Piling which has penetrated 25 feet of sand, gravel and clay. Although there are two special corner sections, two T sections and but three standard piling sections on two faces, and five each on the other two, the rectangle is as nice as could be desired. The unusual combination of sections gave no trouble in assembling or driving.

Lackawanna Steel Sheet Piling



Pit 25 feet in diameter and built with Lackawanna 15-inch Arched-Web Steel Sheet Piling. Illustrating the joint flexibility in conforming to circular constructions. The opening was cut through by an oxygen flame after the steel sheet piling had been driven. A concrete floor has since been laid within, and the opening connected to a sewer.

of contact between the interlocked members of each joint, so that there is a positive, double, firm and close interlock, yet a minimum of friction in driving or withdrawing and ample opportunity for displaced material to work into the joint and assist in rendering it watertight, while at the same time the interlock holds the piling in proper alignment to form the wall.

In the development of this section, special attention was given to secure for this joint the maximum tensional and transverse strength, and at the same time to produce a pile which would be simple, interlock perfectly, and have the material so distributed as to give a section modulus producing the required transverse strength.

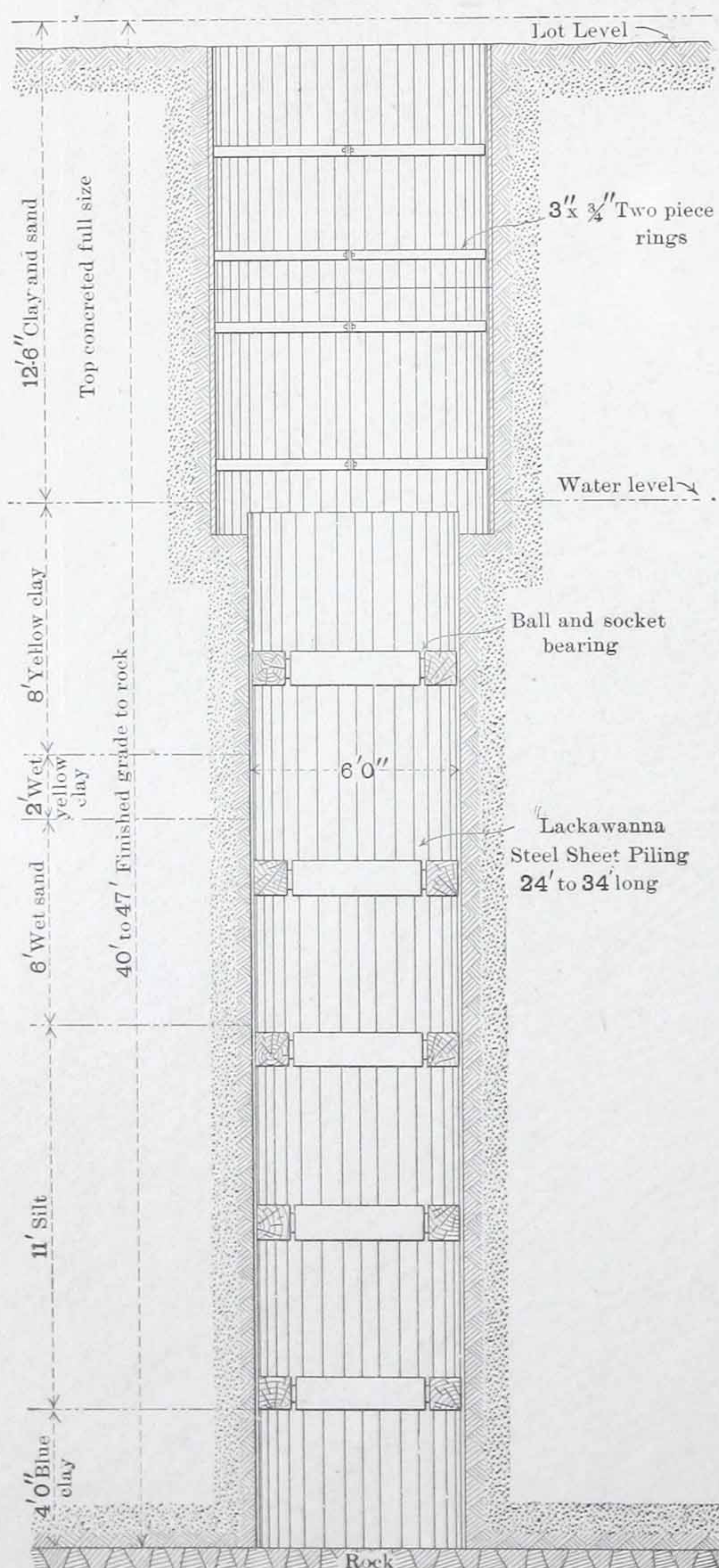
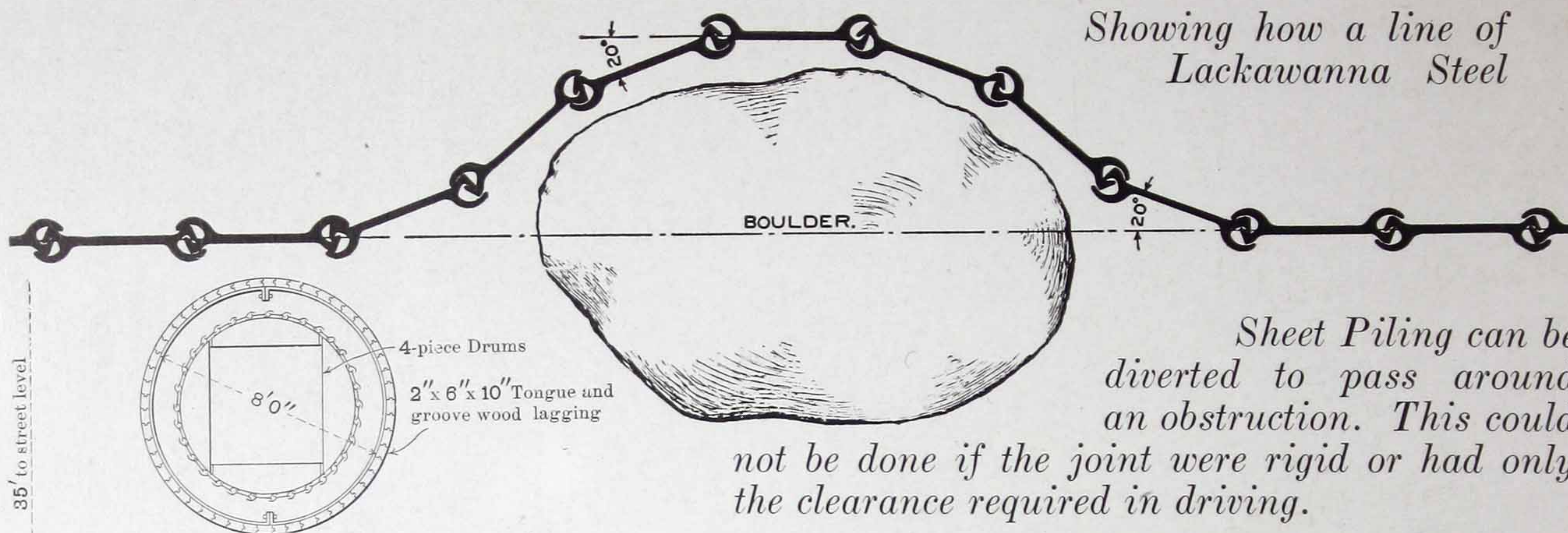
The Lackawanna Sections are shaped to produce a flexible joint between adjacent piles. A change of direction of from 16 degrees to either side of the piling line with the smallest, to 20 degrees to either side with the other Lackawanna sections is quite practical. In other words, a right angle may easily be made with six 7-inch and with five of any other Lackawanna Steel Sheet Piling interlocked joints.

Corners and junction members for walls meeting or crossing each other are fabricated by fitting the edges of half sections to complete sections as required, and holding them in place by structural steel angles and rivets. Special sections to meet all ordinary requirements are shown on page 7.

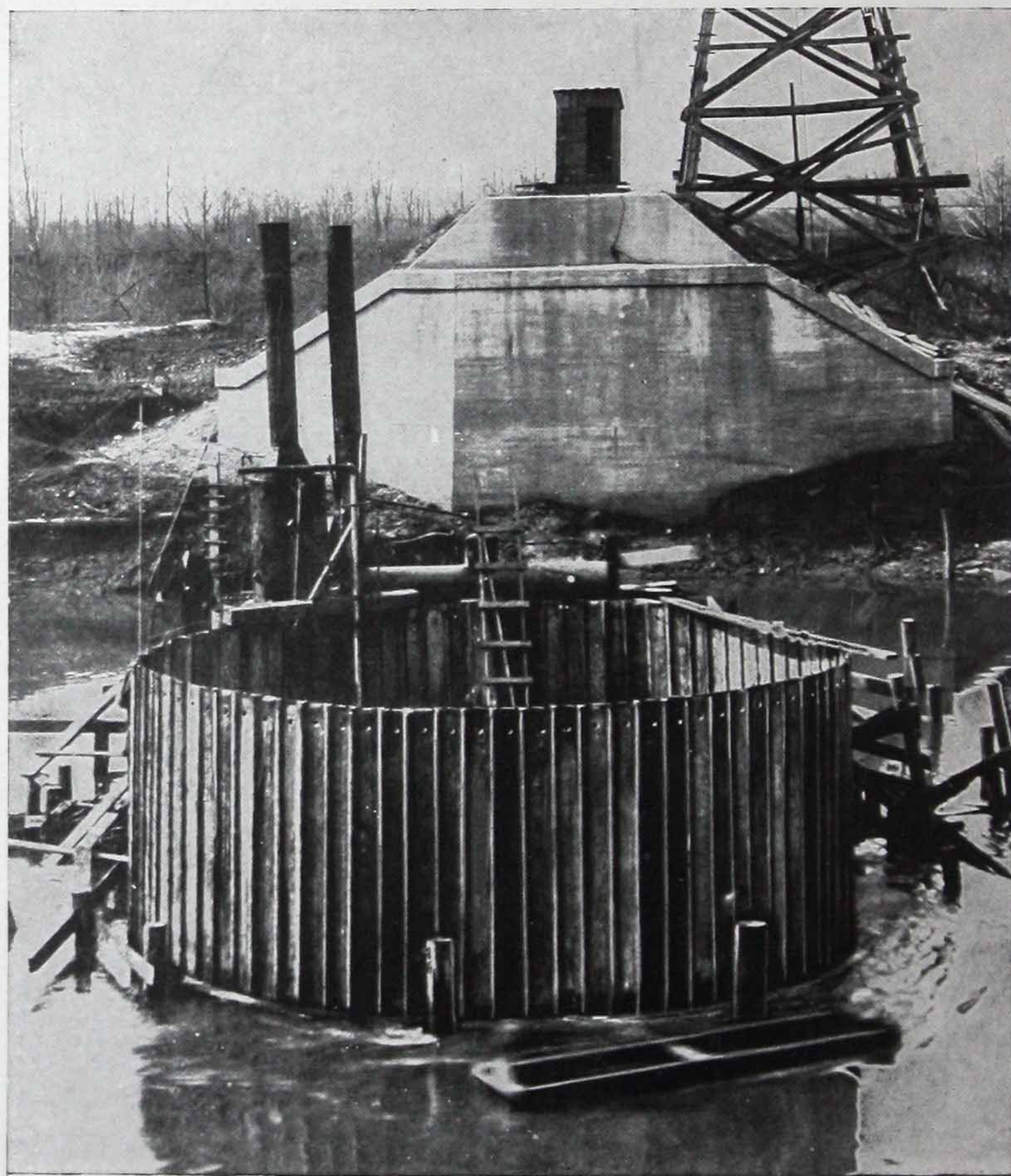
Specials for all types of Lackawanna Piling are



Lackawanna Steel Company



One of 70 typical circular caissons of Lackawanna Steel Sheet Piling for column foundations, Railway Exchange Bldg., St. Louis.



Circular cofferdam of Lackawanna Steel Sheet Piling in which was built the pivot pier of the Ocmulgee River Bridge, Macon, Dublin & Savannah R. R. The piling was in 45-foot spliced lengths, the lower lengths being 30 feet long, and left permanently as a form for the concrete. After completion, the upper or 15-foot piling lengths were removed and re-used.

Lackawanna Steel Sheet Piling

fabricated from the Straight-Web section.

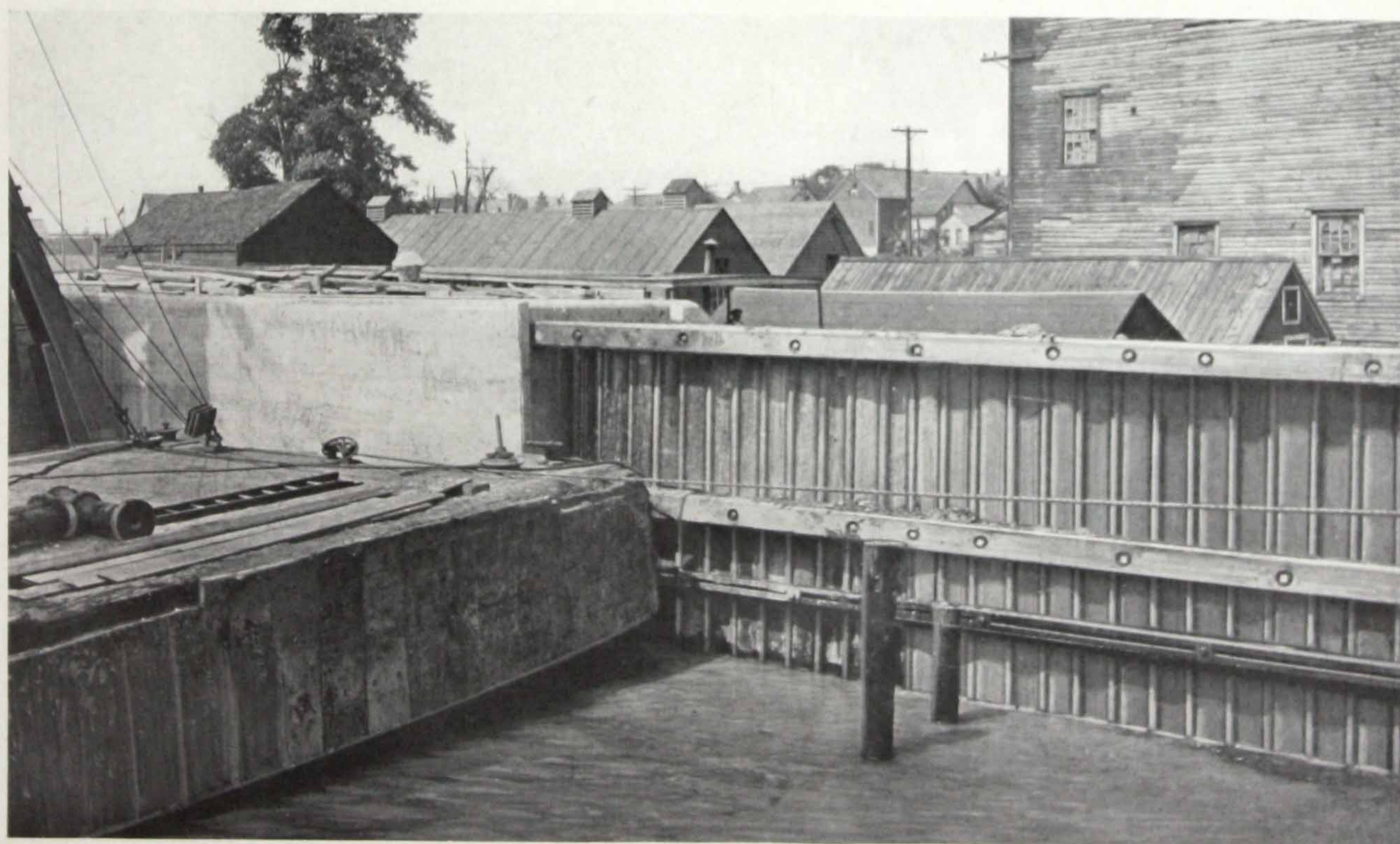
Rolled, 90-degree corners can be furnished as shown on page 7. This type of corner will answer in all but special cases. Rolled corners, with interior angles greater than 90 degrees, will be considered when requested.

The advantages of the Lackawanna flexible interlock, in turning angles to pass obstructions, and to form the small circular or irregular shaped enclosures which are frequently desirable, are clearly shown in the accompanying illustrations. Small sumps, pits for pumps, open caissons for foundations and the like, which would be entirely impossible with most other types of piling can be made from Lackawanna Steel Sheet Piling without bending the webs and without fabrication and the piling may be easily driven and closure made. Typical circular and oval caissons are shown on pages 7, 10, 11, 12, 42, 43, 44, 51, 52 and 53.

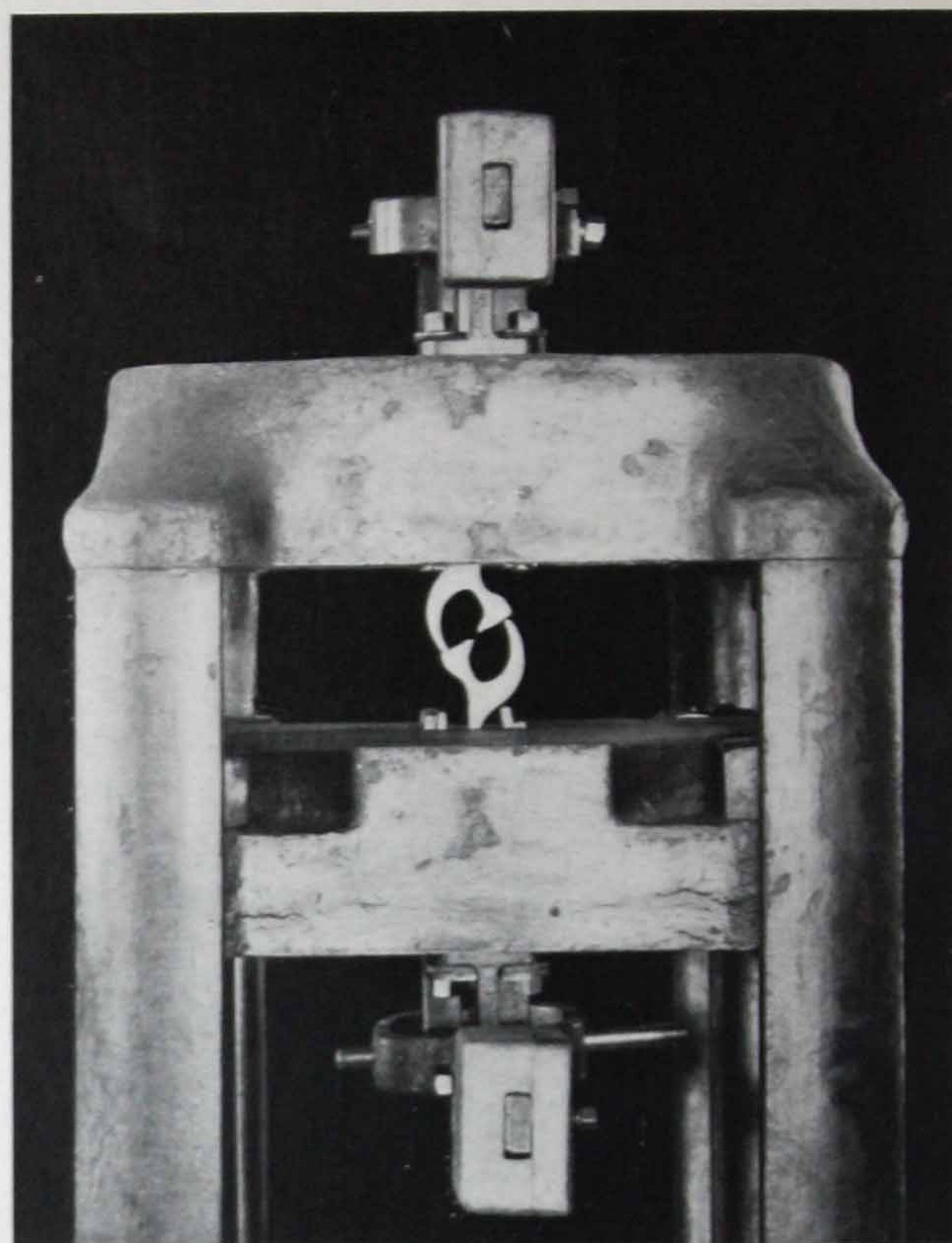
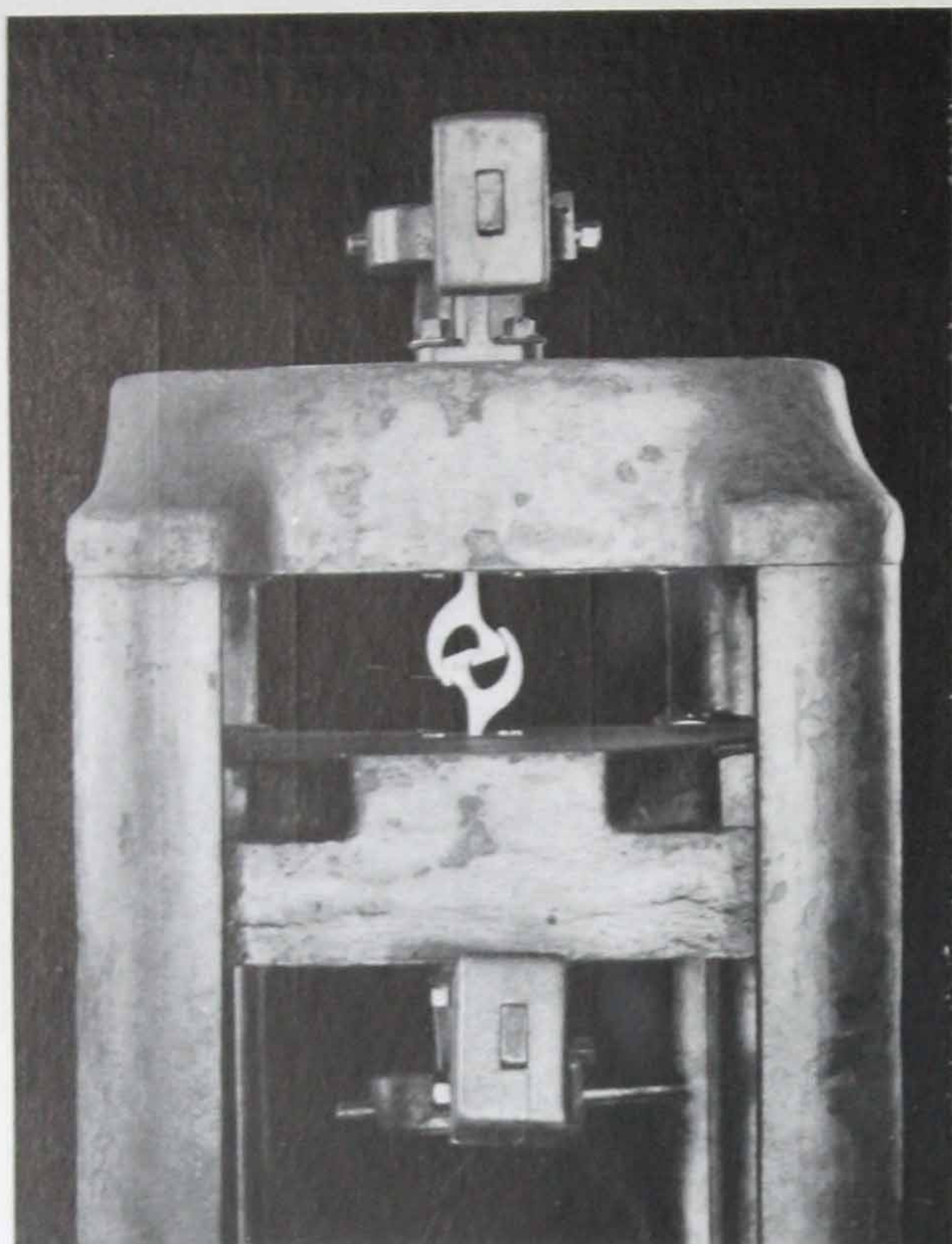
Minimum diameters of circular structures made with Lackawanna Steel Sheet Piling

(An **even number** of piles is required to permit interlocking of the final or closure joint)

Width of pile center to center of joints	7 in.	12 $\frac{3}{4}$ in.	14 in.	15 in.
Number of piles required	24	18	18	18
Deflection angle between piles	15°	20°	20°	20°
Diameter of circle, center to center of piling wall	4' 5 $\frac{5}{8}$ "	6' 1 $\frac{7}{16}$ "	6' 8 $\frac{5}{8}$ "	7' 2 $\frac{3}{8}$ "
Working diameter inside of piling	4' 3 $\frac{5}{8}$ "	5' 9 $\frac{7}{16}$ "	6' 4 $\frac{7}{8}$ "	6' 10 $\frac{1}{4}$ "



Front view of connection between the steel sheet piling wall shown on pages 3, 22, 58 and 59 and the concrete approach walls of large ship lock built by the United States Government at Buffalo, N. Y. The stability of a Lackawanna Steel Sheet Piling wall, constructed by competent engineers, is well illustrated. Where the timber crib and concrete wall join the steel sheet piling wall excavation had been made to a depth of 23 feet to place cribs upon which to construct the concrete wall. The earth pressures behind the wall at this particular point were therefore excessive.



An interlocked joint of Lackawanna Steel Sheet Piling clamped in the Olsen testing machine, before and after test for the ultimate tensile strength of the joint.

Strength of the Lackawanna Interlock

THEORETICALLY the strength of the interlocked joint, under tensional and transverse stress, should be high in proportion to the strength of the web of the pile under similar stress, without, however, causing excessive weight and using more metal than will interfere with easy driving to final position and subsequent performance of duty.

In other words, the strength of a piling wall, before bracing or tying against horizontal or oblique pressure, is largely dependent upon the strength of the interlock, thus making the joint strength one of the most important considerations.

Every impartial test made has demonstrated that the Lackawanna interlock is by far the strongest, under tension, of any on the market. This tensional strength is due to the three-point contact, the distribution of metal in interlocking joint members and their relation to the longitu-

dinal axis of the piling section.

The Lackawanna Steel Sheet Piling ($12\frac{3}{4}$ -inch Straight-Web section) which went into the cofferdam for raising the U. S. Battleship Maine was guaranteed to develop an ultimate tensile strength of 9,700 pounds per lineal inch of interlock. The results of actual tensile tests on the interlocks of this piling were as follows: The lowest tensile strength per lineal inch of joint was 9,764 pounds and the next lowest 9,944 pounds; these were the only two, of all the tests, which gave an ultimate strength below 10,000 pounds; other tests showed results ranging from 10,000 to 16,000 pounds, the average being 11,975 pounds per lineal inch of joint.

The interlocked joints of steel sheet piling in addition to resisting stresses due to driving, maintaining alignment and passing obstructions must also have high tensional and transverse strength. This is essential to assure that a steel sheet piling wall, partially or wholly subjected to sudden or unexpected heavy load, will hold together without

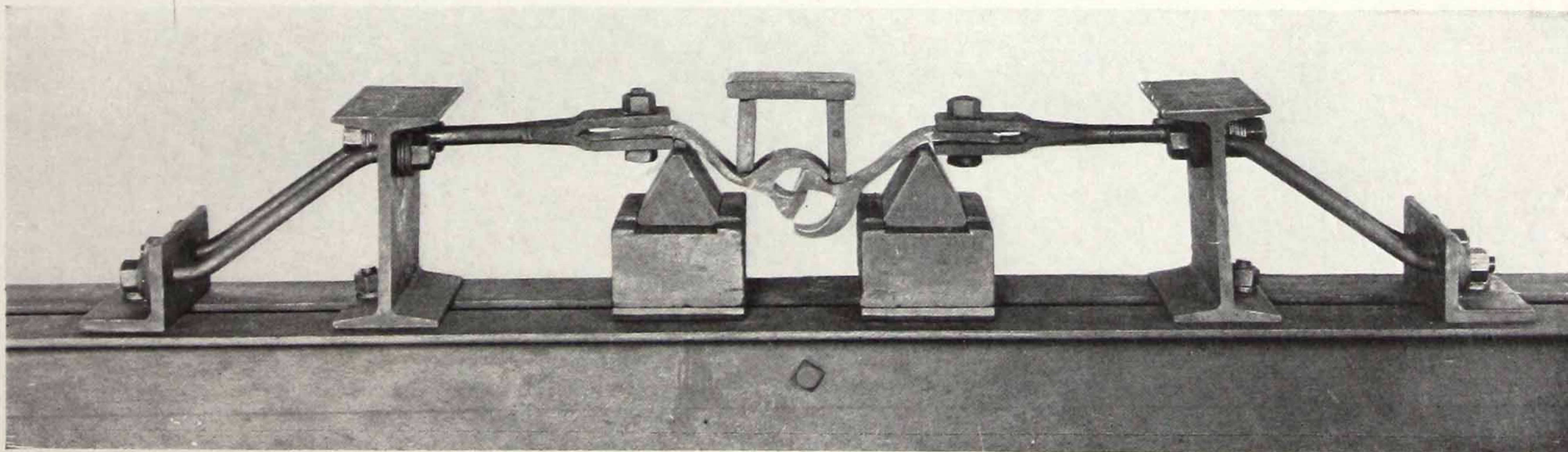
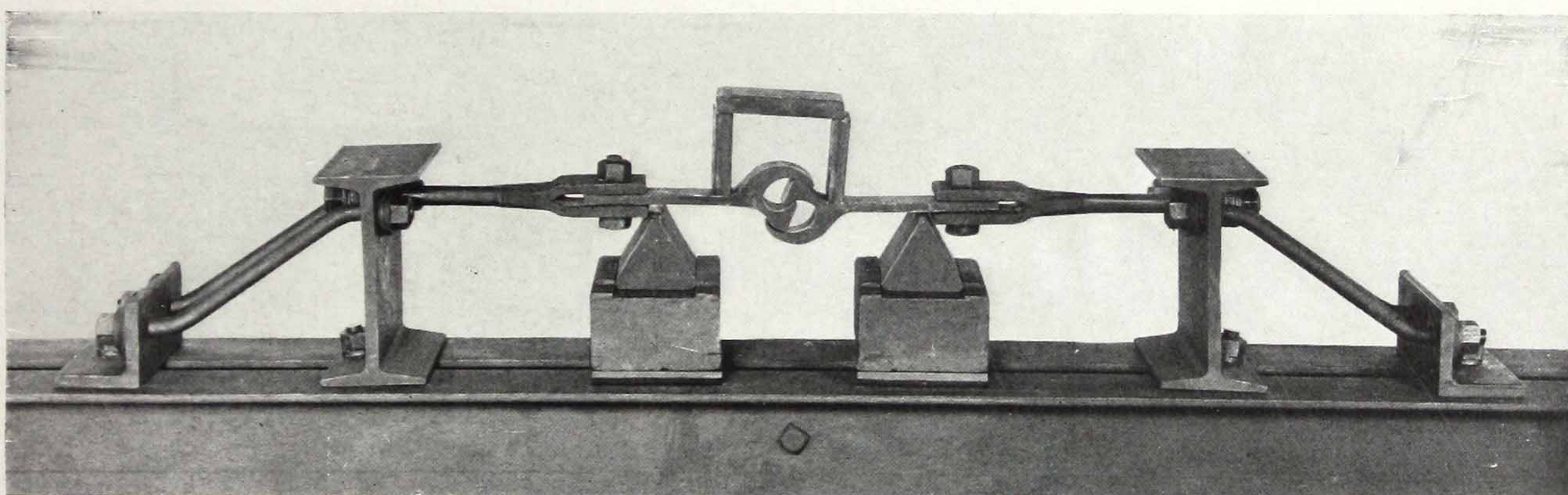
~ Lackawanna Steel Sheet Piling ~

requiring an excessive quantity of interior bracing or exterior tie rods.

Competitive tension tests conducted in an entirely disinterested manner, and under government supervision, were made on five different makes of piling, using on each, methods best adapted to bring out the best results. The sections were tested on an Olsen machine, as indicated in the photograph, and with one exception weighed approximately 40 pounds per square foot. These tests, which are described more fully in our Bulletin No. 103, and which resulted in the exclusive use of Lackawanna Steel Sheet Piling in the Cofferdam for the Government Ship Lock at Black Rock, Niagara River, summed up as indicated in the accompanying table:

<i>Make of Piling</i>	<i>Average breaking load per inch of length</i>	<i>Relative holding strength of jaw</i>
<i>Lackawanna</i>	9,746	1.00
<i>Other types</i>	3,842	0.394
	1,094	0.112
	3,362	0.345
	7,769	0.797

Since these tests, our Arched-Web sections, which also give far greater transverse strength as represented by the section modulus, especially the section modulus *per inch of width of pile*, the only safe and correct comparison, have been developed, thus giving Lackawanna Steel Sheet Piling unquestioned supremacy in both interlocking and transverse strength.

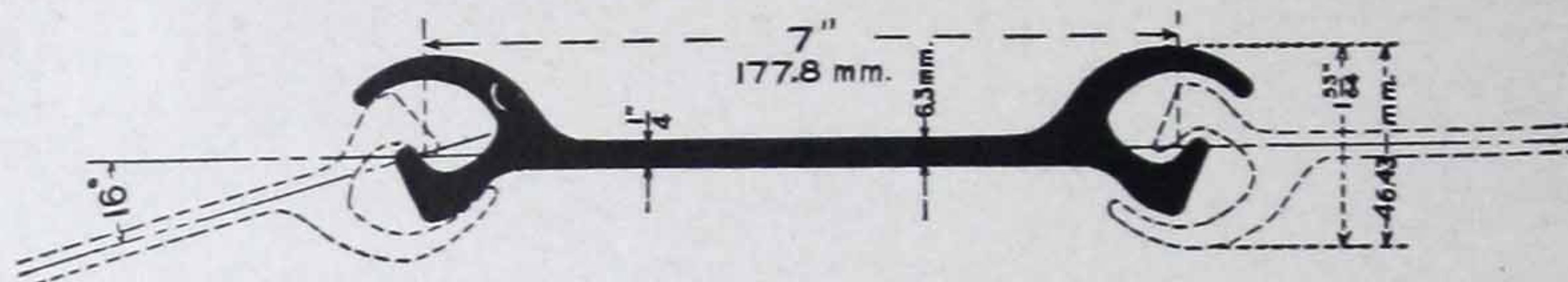


Part sections of Lackawanna Steel Sheet Piling assembled for a joint-bending or a transverse distortion test of joint. These bars were two inches long and the load was applied at points 2½ inches each side of center of joint. A continuously increasing load was applied, and the second view was taken when the load was 20,400 pounds, or 10,200 pounds per inch. In spite of the extreme distortion under this heavy eccentric loading, one lock still held intact. Increasing the loading to 35,400 pounds or 17,700 pounds per inch, the joint was pulled apart.



Types, sections, dimensions and weights of Lackawanna Steel Sheet Piling

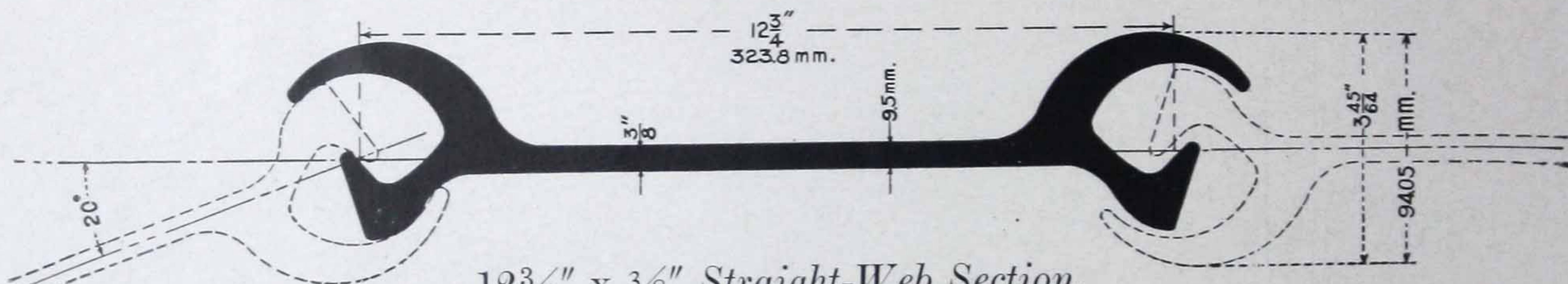
Straight-Web type. This type is for general work and more especially for walls and constructions requiring high tensional and compressive resistance of the pile section, as in self-contained cofferdams made up of a series of square, circular, semi-circular and other filled pockets. In these instances, the stresses in the individual piling bars are apt to be mostly tensional, being due to pressure from filling material within pockets, and are transmitted through interlocked joints from pile to pile.



7" x 1/4" Straight-Web Section.

21.5 pounds per square foot of wall.

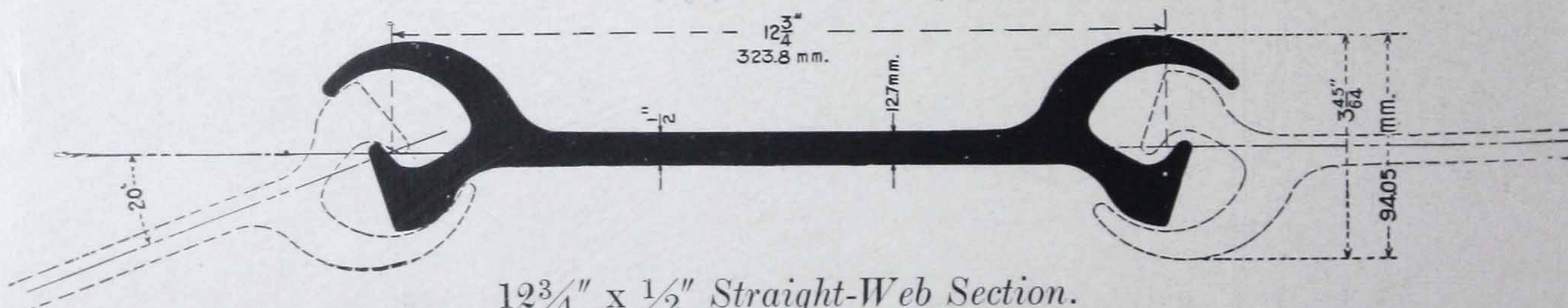
12.54 pounds per lineal foot of bar.



12 3/4" x 3/8" Straight-Web Section.

35 pounds per square foot of wall.

37.187 pounds per lineal foot of bar.



12 3/4" x 1/2" Straight-Web Section.

40 pounds per square foot of wall.

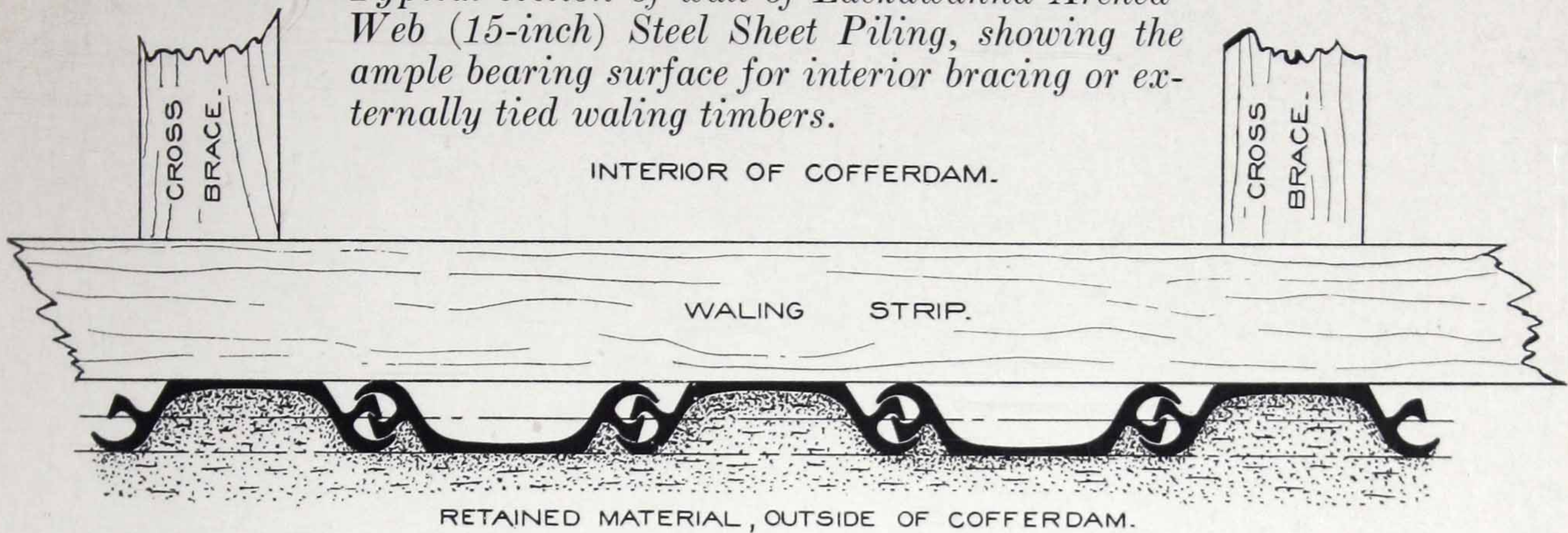
42.5 pounds per lineal foot of bar.

Arched-Web type. This type of piling is by far the strongest and most economical on the market where transverse strength of the pile, as represented by the section modulus, is of primary importance, as in cofferdams, caissons and other constructions where the sheet pile acts as a simple, continuous, or cantilever beam. A wall of Lackawanna Arched-Web Steel Piling in comparison to a similar wall of plain straight-web piling under the same conditions has greater transverse or beam strength, due to the higher section modulus of the individual piling section, per unit of width of pile, and consequently higher resistance against bending moment.

The distinguishing feature of the Lackawanna Arched-Web Section is the curving or arching of the web in such a way that the mass of metal within the web lies to one side of the neutral axis of the section. Referring to page 17, the outer face of the web, or what might be termed the extrados of the arch, is flattened to lie in the same vertical plane with the extreme outer face of the interlock. In the piling wall, the arches reverse with each pile, bringing each succeeding web on the opposite side

Lackawanna Steel Sheet Piling

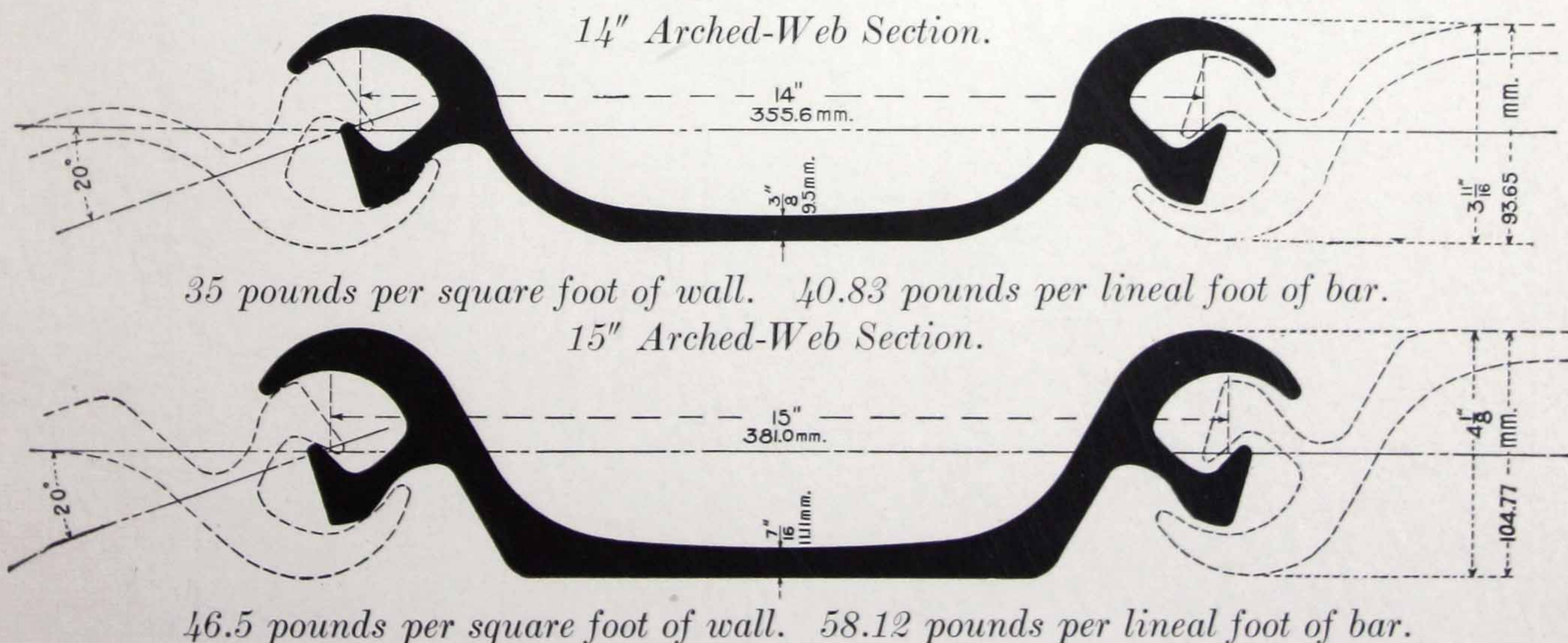
Typical section of wall of Lackawanna Arched-Web (15-inch) Steel Sheet Piling, showing the ample bearing surface for interior bracing or externally tied waling timbers.



of the neutral axis of the wall. At the same time, the Arched-Web Section transmits the load to the supports with less tendency to flatten out.

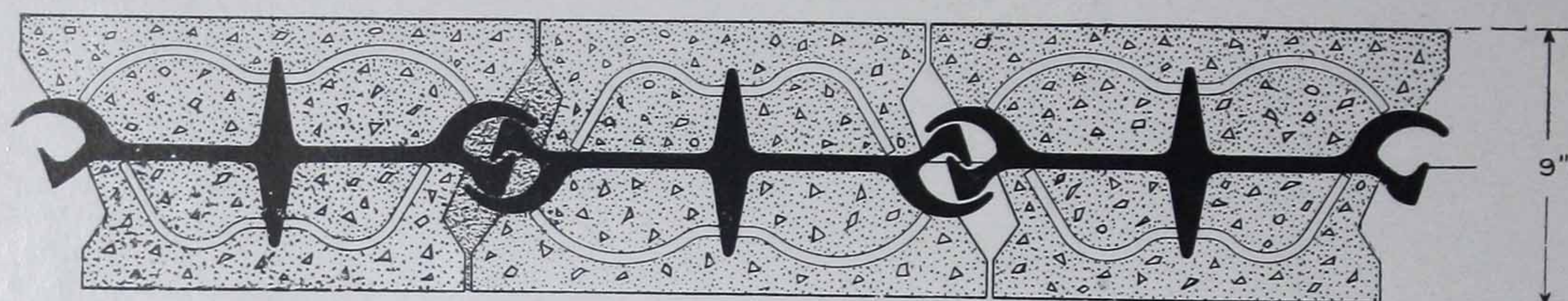
The metal is thickened at the haunches of the arch, giving increased strength at these points against spreading and also distributing the metal in the web with reference to the neutral axis so as to increase the moment of inertia and section modulus. From the sketch above, it will be seen that where the external side of the arch receives the pressure from the retained material, this pressure is transmitted to the waling timber, partially through the interlock directly, and is also partially distributed through the interlock into the next web, which itself bears directly upon the waling timber. Those piles which receive the pressure on the internal side of the arch transmit the pressure directly through the web to the waling timber over a wide bearing surface, which is much increased by thickening the metal at the haunches, as stated.

This Arched-Web section gives increased transverse and columnar strength, and permits the construction of a wall that is thin and compact in proportion to its lateral strength. (A wall of Lackawanna Arched-Web Sheet Piling is no thicker overall at any point than the overall thickness of the interlocked joints.) It also permits a greater vertical spacing between supports or waling timbers, thereby reducing the amount of timber required for a given loading and thus effecting economy where transverse strength is a primary consideration.



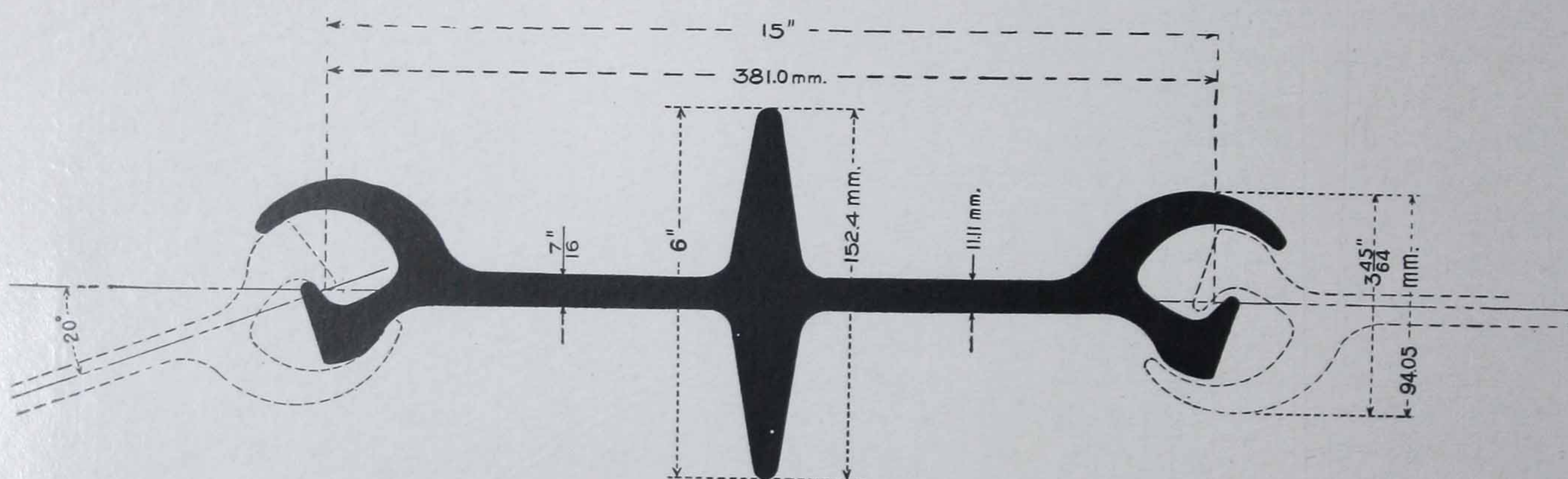


Center-Flange type. This type is designed for constructions requiring high tensional and compressive strength in the pile section, together with a fairly high transverse strength. The Center-Flange, as rolled on this section, acts as a stiffener



Showing use of center-flange and tie rods in binding on protective concrete facing.

to the web, increases the modulus of the section and furnishes a means for attaching transverse ties, braces, etc., needed in special work, and tie rods used in binding on protective concrete facing in permanent protected constructions.



15" x $\frac{7}{16}$ " Center-Flange Section.

48 pounds per square foot of wall.

60 pounds per lineal foot of bar.

Sections	Weight per lineal unit of bar		Weight per unit area of wall	
	Per lineal foot in pounds	Per lineal meter in kilograms	Per square foot in pounds	Per square meter in kilograms
7" x $\frac{1}{4}$ " Straight-Web	12.54	18.60	21.5	104.97
12 $\frac{3}{4}$ " x $\frac{3}{8}$ " Straight-Web . .	37.187	55.36	35	170.90
12 $\frac{3}{4}$ " x $\frac{1}{2}$ " Straight-Web . .	42.5	63.25	40	195.32
15" x $\frac{7}{16}$ " Center-Flange	60.00	89.29	48.00	234.34
14" x $\frac{3}{8}$ " Arched-Web	40.83	60.76	35	170.90
15" x $\frac{7}{16}$ " Arched-Web	58.12	86.49	46.5	227.02

Lackawanna Steel Sheet Piling

Efficiency of Lackawanna Steel Sheet Piles in transverse strength

As represented by Coefficient of Strength per pound of metal in a
pile beam 12 inches long

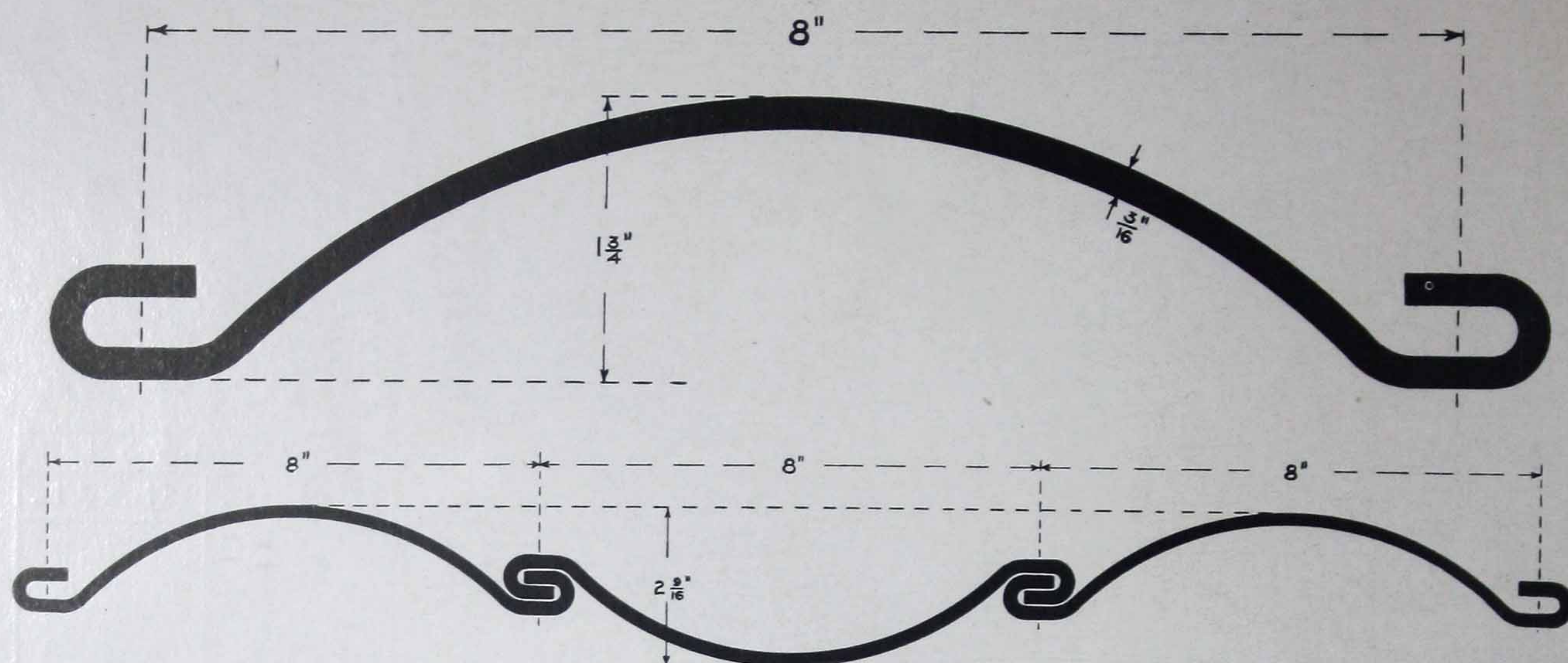
(The load on a sheet pile in position, while retaining fluid, semi-fluid or more dense materials, increases directly as the width of the pile. Therefore, the modulus and moment of resistance of the pile section must also increase directly as the width of the pile.)

Type Size	Straight-Web			Center-Flange	Arched-Web	
	7 in. x $\frac{1}{4}$ in.	$12\frac{3}{4}$ in. x $\frac{3}{8}$ in.	$12\frac{3}{4}$ in. x $\frac{1}{2}$ in.	15 in. x $\frac{7}{16}$ in.	14 in. x $\frac{3}{8}$ in.	15 in. x $\frac{7}{16}$ in.
Least radius of gyration of single section.	0.373	0.760	0.729	1.01	1.150	1.290
*Modulus of interlocked sections, center to center of web.	0.575	4.040	4.210	6.25	8.890	14.110
Modulus of single section.	0.567	4.000	4.120	5.73	7.610	11.800
Modulus per inch of width of single section.	0.081	0.313	0.323	0.382	0.543	0.786
Efficiency in transverse strength of single section, weight not considered.	†1.00	3.86	3.98	4.72	6.70	9.70
Coefficient of strength, factor of safety 3, fiber stress taken at 20,000 lb. per sq. in.						
$\frac{3}{2} \left[20,000 \times \frac{\text{modulus of single section}}{\text{weight in pounds, lin. foot of pile}} \right]$	7560.00	53333.33	54933.33	76400.00	101466.66	157333.32
Weight in pounds, lin. foot of pile	12.54	37.187	42.50	60.00	40.83	58.12
sq. foot of wall	21.50	35.00	40.00	48.00	35.00	46.5
Coefficient of strength of single section per pound of metal = $\frac{\text{coeff. of strength}}{\text{wt. of lin. ft. of pile.}}$	602.87	1434.19	1292.54	1273.33	2485.10	2707.04
Efficiency considering both transverse strength and weight, or the coefficient of strength of single section per pound of metal.	†1.00	2.37	2.14	2.11	4.12	4.49

*It is safer not to use the interlocked modulus in designing steel sheet pile structures, unless, as in permanent constructions, the open spaces remaining in the interlocked joints of the piling, after driving, are filled with cement grout before pressure is brought upon the wall; thus preventing movement of the interlocking members of the joint and also preventing a change in position of the neutral axis of the wall.

The modulus of the single pile section, while somewhat lower, is more conservative, as the neutral axis of such single section is not so subject to change of position after the pile is installed in the wall.

†Taken as the basis for comparison.



Lackawanna Plate Sheet Piling. Note particularly the highly desirable mathematical qualities of this section as shown in the following table:

Width: 8 inches between joint centers.

Thickness of metal: $\frac{3}{16}$ inch.

Thickness of wall: $2\frac{9}{16}$ inches.

Weight per square foot of wall: 11.50 pounds.

Weight per lineal foot of piling section: 7.66 lbs.

Modulus of single section: 0.74.

Modulus per inch of width of single section: 0.0925.

Moment of resistance in inch-pounds with factor of safety = 4, or fibre stress taken at 16,000 pounds per square inch, 11840.

Least radius of gyration of single section: 0.536.

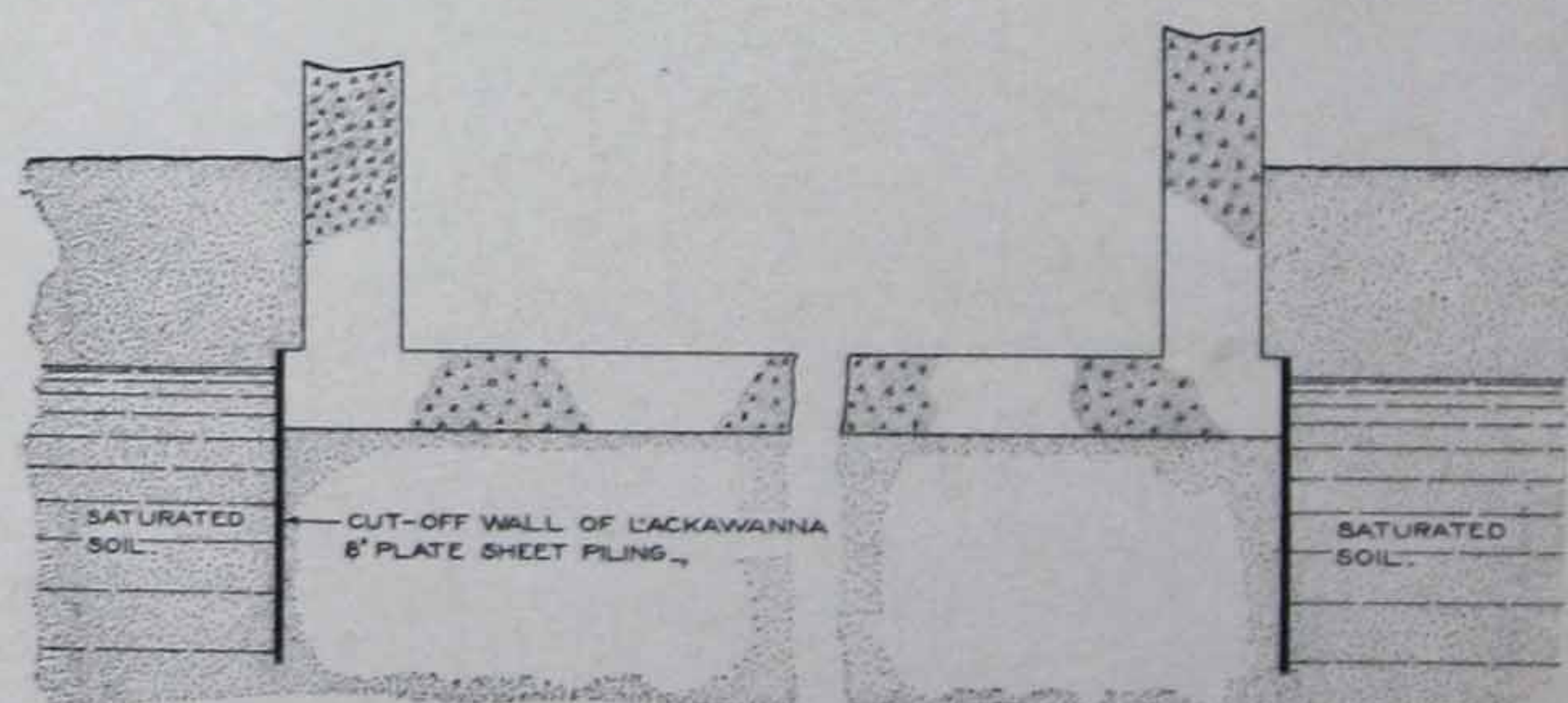
Lackawanna Plate Sheet Piling

LACKAWANNA Plate Sheet Piling is cold rolled from steel plate into a type of section designed for use principally under the following conditions:

1. Where great economy demands a very low weight and cost per square foot of wall,—lower than obtainable with the heavier sections of steel sheet piling.
2. Where the sheet piling need not be driven in very long lengths or in dense material causing hard penetration.
3. Where transverse strength of the sheet piling is secondary, due to material remaining in position on both sides of the wall and neutralizing the lateral pressures.
4. Where high resistance against the passage of water through the interlocked joints is essential. This of course implies a joint strength sufficient to assure installation of the piling wall without the opening or disarrangement of the joints.
5. Where the sheet piling must resist rotting

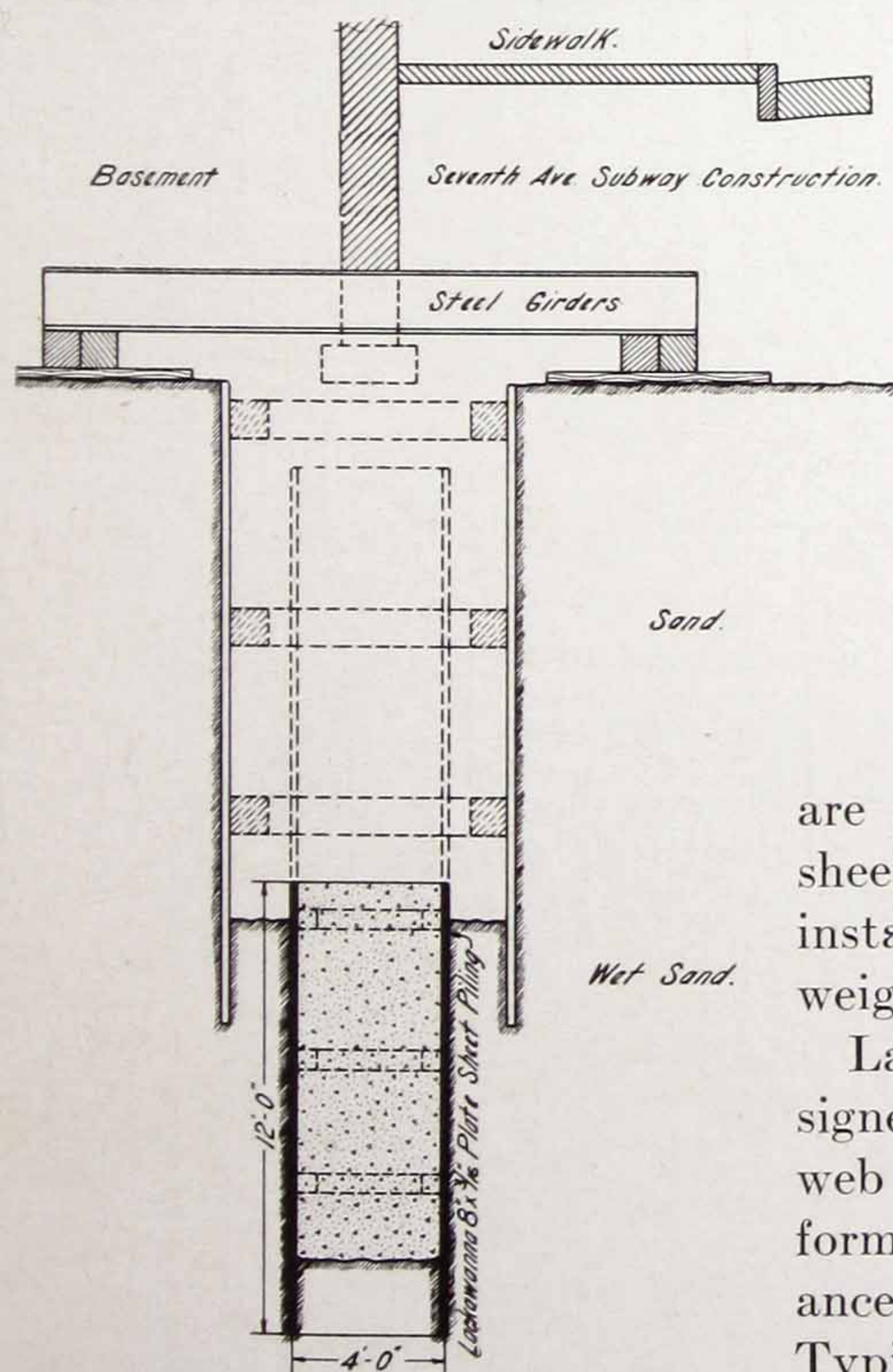
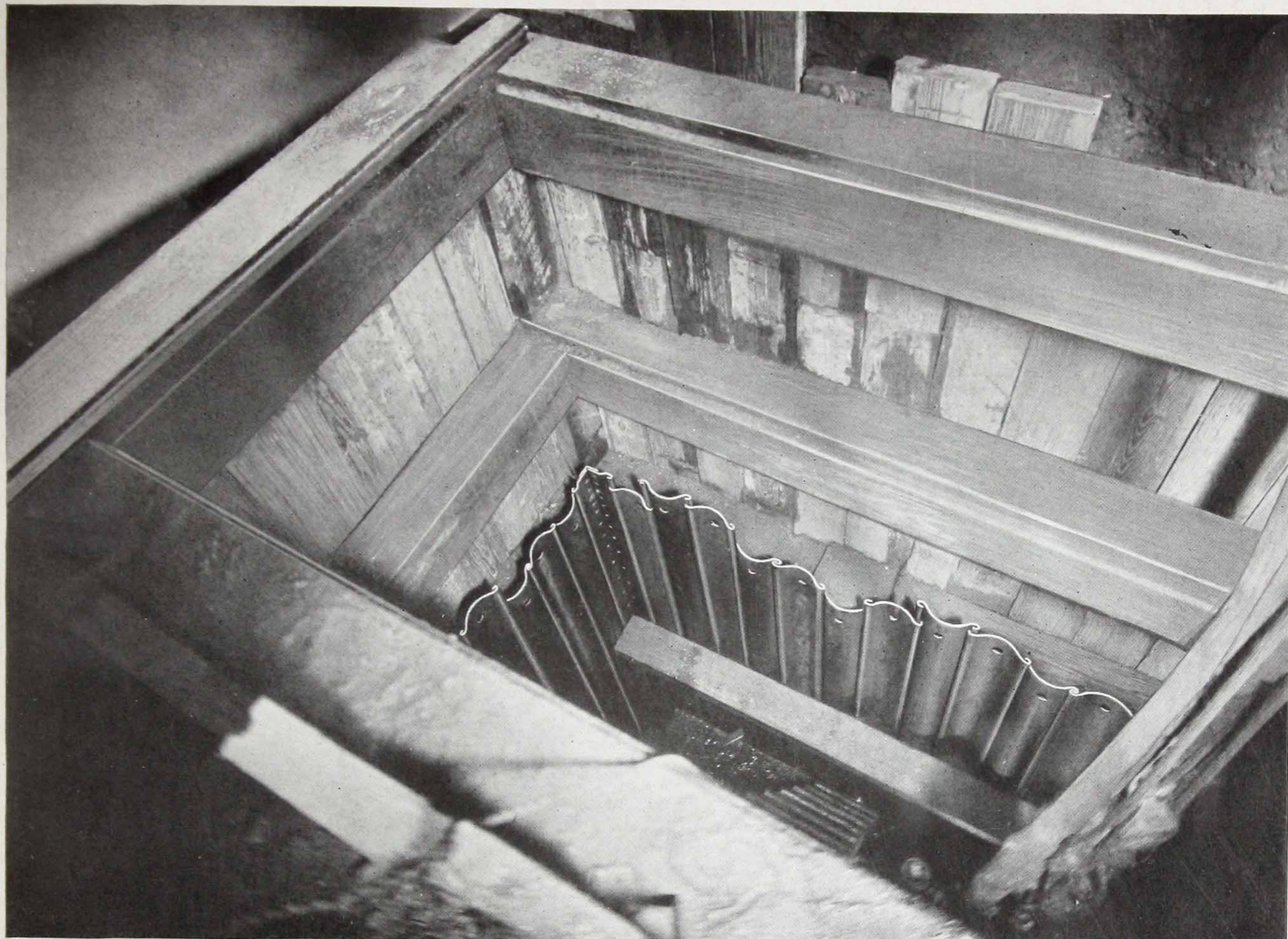
action of the teredo, and other influences which would make timber sheet piling constructions short lived. Steel plate sheet piling, if carefully painted, affords a *permanent* construction well able to resist any ordinary corrosive action from earth, water or moisture.

From this, it is evident that the Lackawanna Plate type of sheet piling is especially desirable for permanent work in cut-off walls under levees, for core-walls in earth dams and embankments (see diagrams, page 40) and for cut-off walls underneath masonry foundations where the latter



Permanent cut-off wall of Lackawanna Plate Sheet Piling to surround a masonry foundation built in saturated soil.

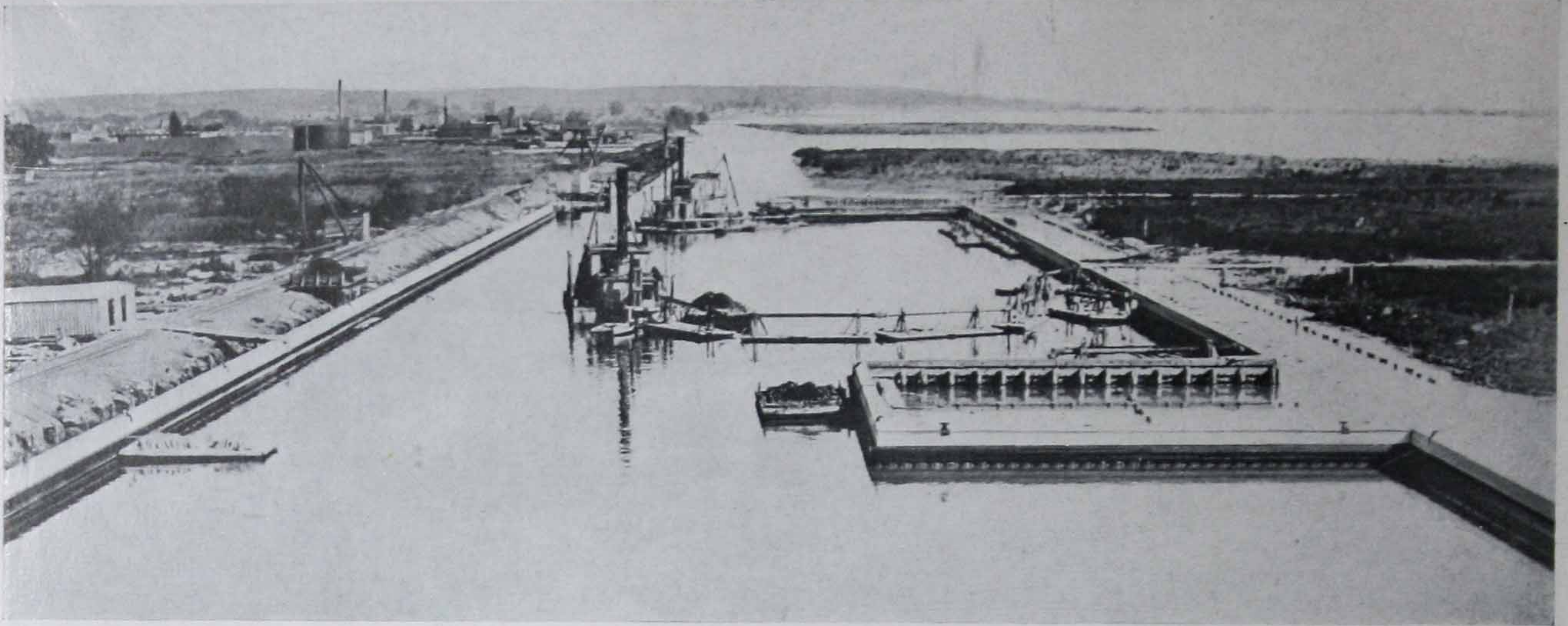
Lackawanna Steel Sheet Piling



Lackawanna 8-inch Plate Sheet Piling used in open caissons for underpinning on New York subway work. Caissons about 4 by 8 by 12 feet were put together and lowered through the upper shaft, then driven through sand to final position. Excavation was carried down with the piling where boulders were encountered. These caissons were finally filled with concrete and the steel sheet piling left permanently in position.

are constructed in saturated soils. In general this type of steel sheet piling will demonstrate economic structural advantages in installations where a permanent impermeable wall of very light weight is required to prevent the passage of water.

Lackawanna Plate Sheet Piling comes from a mill specially designed for its manufacture. All sections are uniform, have an arched web to give columnar and transverse stiffness, and have a simple form of interlock which gives free driving with the necessary resistance against the passage of water through the interlocked joint. Typical methods of driving are illustrated on page 49.

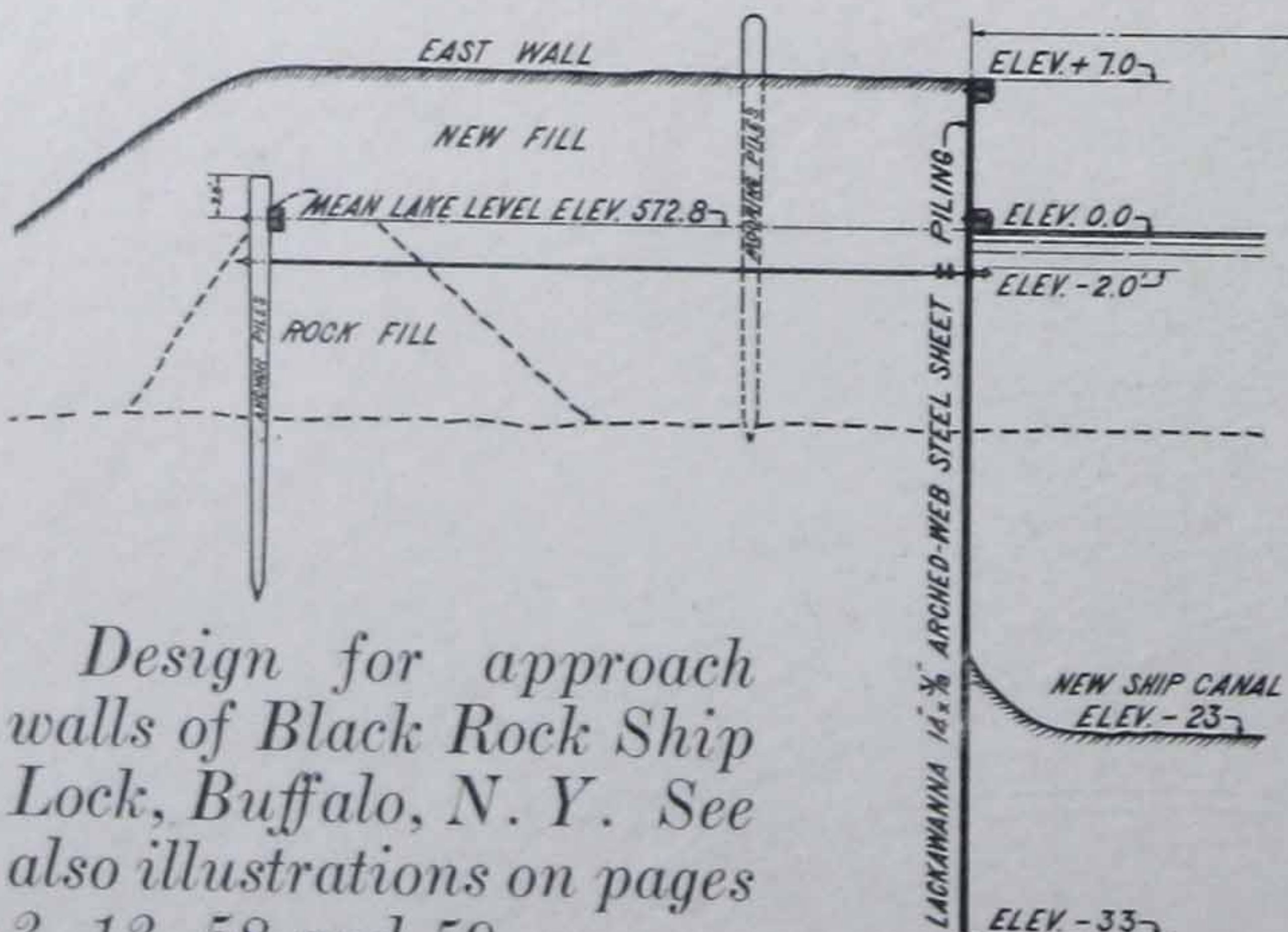
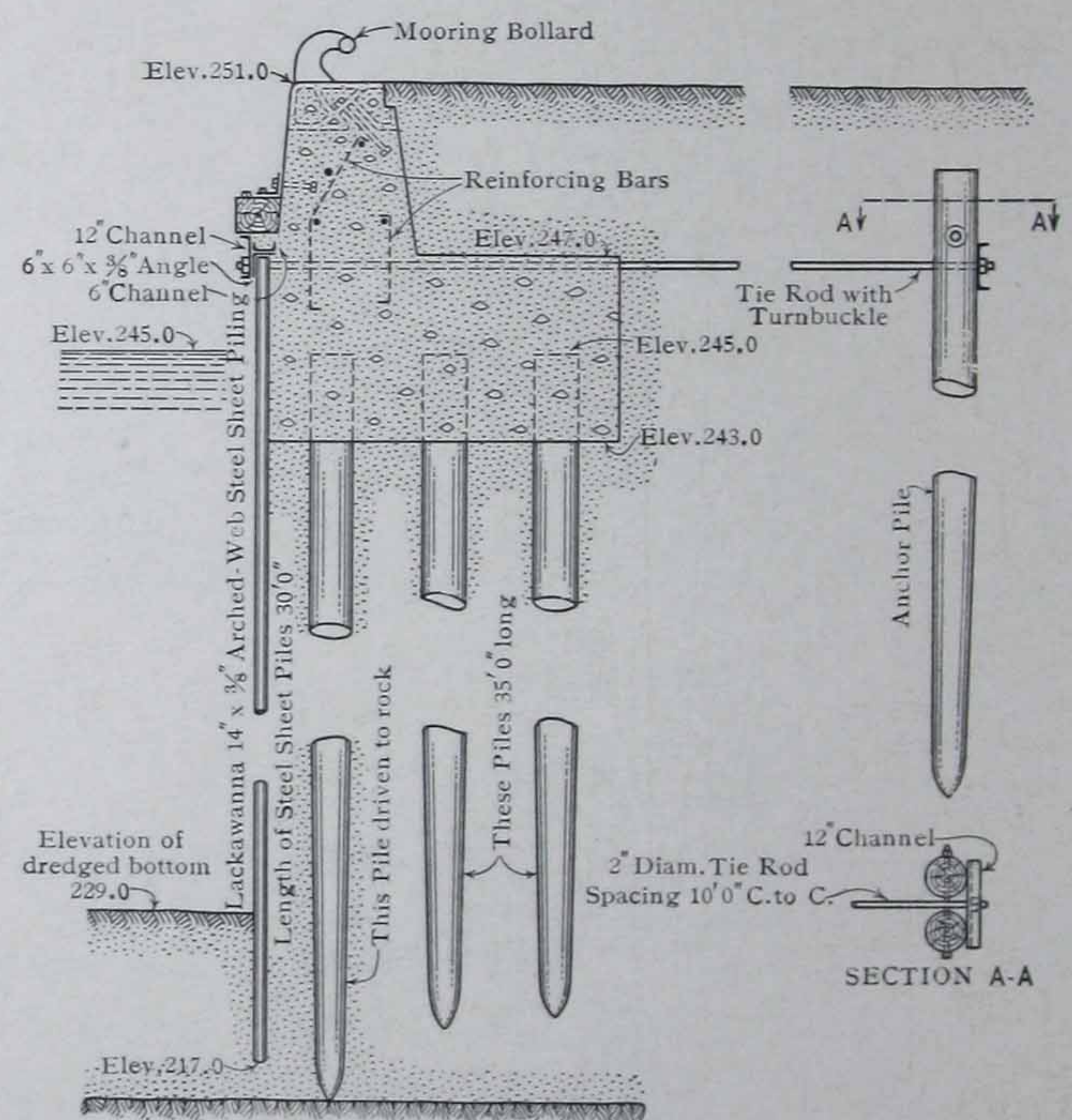


2600 lineal feet of dock on the Don River Diversion, and (at the right) the design adopted for this work by E. L. Cousins, Engineer, Toronto Harbor Commission. Further details shown on opposite page.

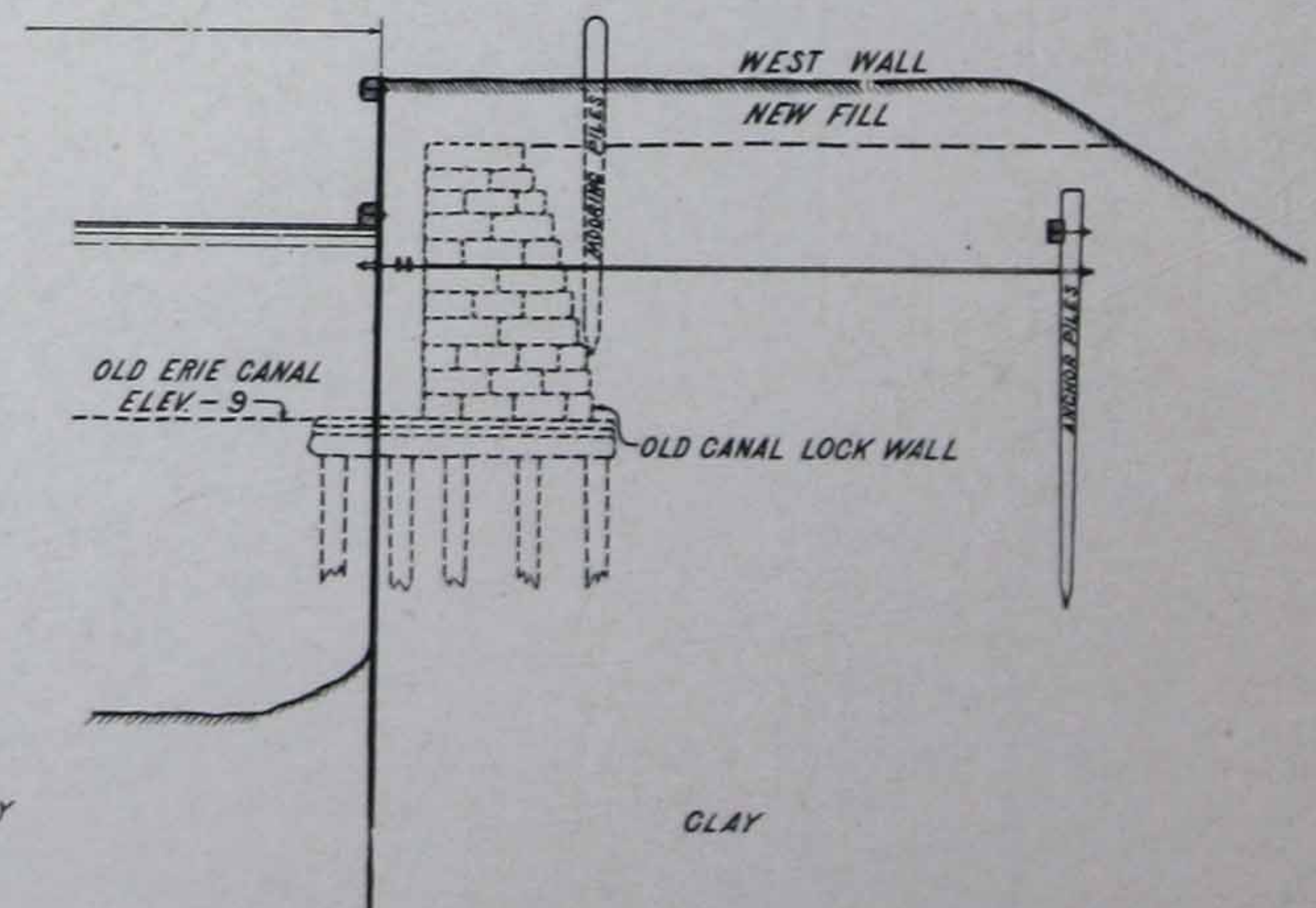
Lackawanna Steel Sheet Piling as permanent building material in dock construction

THE strength, economy and advantages of permanent installations of steel sheet piling, either alone or in connection with concrete and timber, have now been demonstrated in numerous important instances.

The dredging out of estuaries of southern rivers is causing salt water to flow further inland and this, in connection with the dry seasons, causes

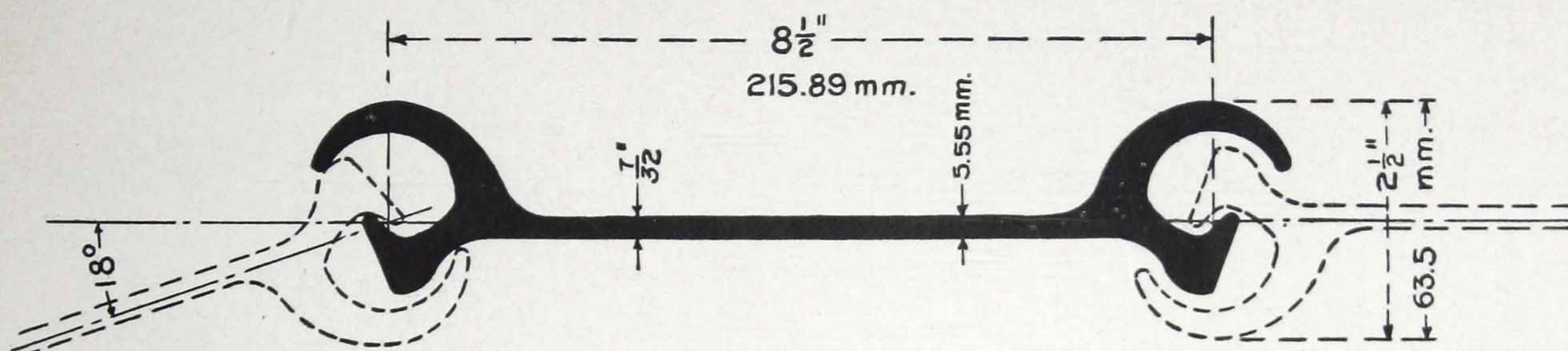


Design for approach walls of Black Rock Ship Lock, Buffalo, N. Y. See also illustrations on pages 3, 13, 58 and 59.



Lackawanna Steel Sheet Piling

8½ Inch—the New Section of Lackawanna Straight-Web Steel Sheet Piling



WEIGHT.		TRANSVERSE STRENGTH.			MODULUS OF SECTION.	LEAST RADIUS OF GYRATION	REMARKS.
LBS PER SQ. FT.	LBS PER LIN. FT.	PER SINGLE SECTION.	PER INCH OF WIDTH.	AVERAGE SECTION MODULUS PER HORIZONTAL FOOT OF WALL INTERLOCKED IN PLACE.			
20.75	14.698	1.100 In. ³	0.1294 In. ³	1.553 In. ³		0.509 In.	<i>The efficiency of this pile per pound of metal (considering that the load will be in proportion to its width, also considering its high transverse strength and low weight) is comparatively very high, as can be demonstrated.</i>
PER SQ. METER IN KILOGS.	PER LIN. METER IN KILOGS.	PER SINGLE SECTION.	PER CENTIMETER OF WIDTH.	AVERAGE SECTION MODULE PER HORIZONTAL METER OF WALL INTERLOCKED IN PLACE.		LEAST RADIUS OF GYRATION.	
101.314	21.873	18.024 Cm. ³	0.835 Cm. ³	83.478 Cm. ³		1.293 Cm.	

THE addition of this new Straight-Web Section fills the one gap in our already large number of types and sizes, and on certain medium and light trench work, cofferdams, retaining walls, etc., gives users of Lackawanna Steel Sheet Piling a little more economical sheeting than was heretofore obtainable.

All the good Lackawanna qualities—simple

flexible watertight interlock with minimum driving and pulling friction—will be found in this section in the same degree as has made the other Lackawanna sections supreme in their various fields of usefulness.

Further information and advice concerning special uses for this section will be furnished on application.

LACKAWANNA STEEL COMPANY

General Sales Office and Works: Lackawanna, N. Y.

NEW YORK
BOSTON

BUFFALO
PHILADELPHIA

CLEVELAND
CINCINNATI

CHICAGO
DETROIT

ST. LOUIS
ATLANTA

SAN FRANCISCO

Licenseses for the manufacture of Lackawanna Steel Sheet Piling:

For Great Britain and British Colonies in the Eastern Hemisphere, Cargo-Fleet-Iron Co., Ltd., Middlesbrough, England. For France, Italy, Spain, French Colonies and Protectorates, Italian Colonies and Spanish Colonies in the Eastern Hemisphere: Cie Des Forges & Aciéries de la Marine et d'Homécourt, Paris, France.

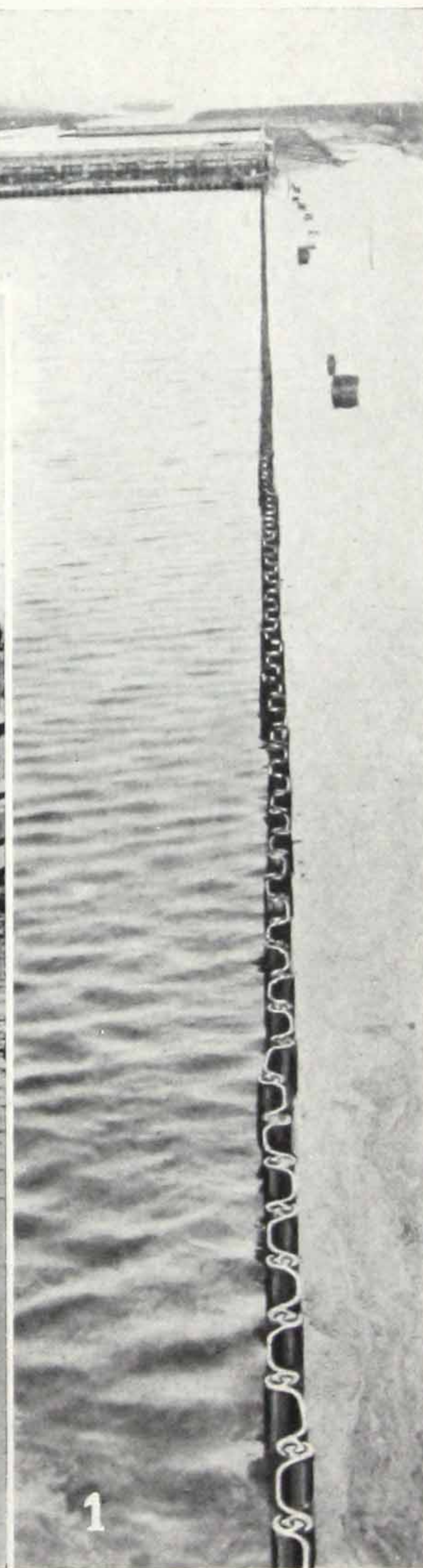
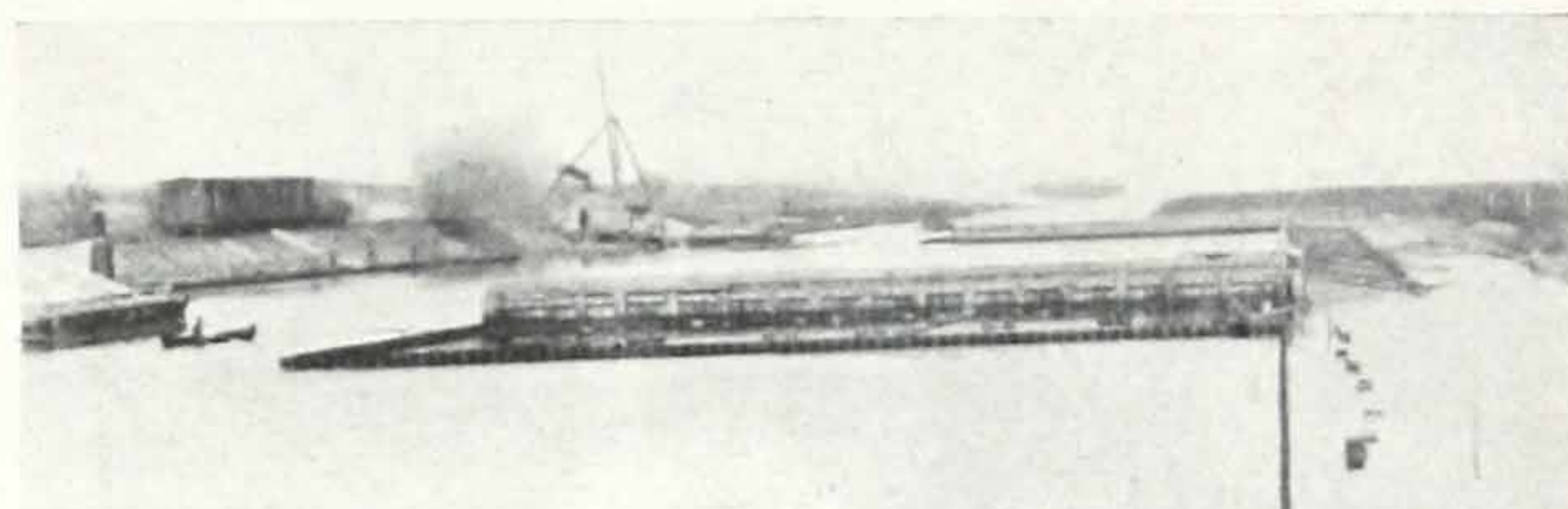
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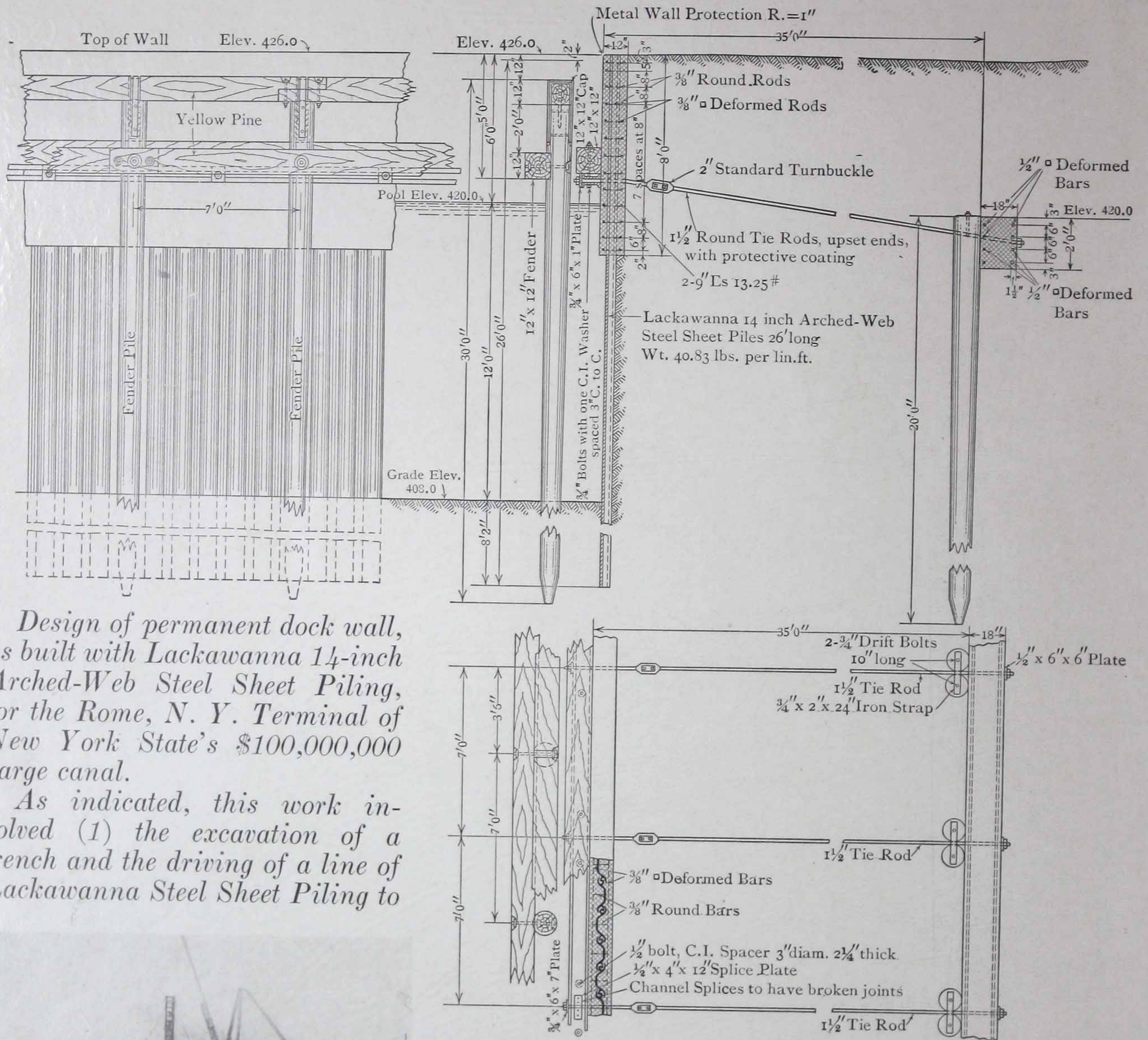
Lackawanna Steel Sheet Piling

Dock details, Don River Diversion, Toronto. (See page 22.) Timber bearing piles and concrete are used and 1,500 tons of 14-inch by 3/8-inch Lackawanna Arched-Web Sheet Piling is permanently installed in front of the concrete wall to retain filled material and material in original position underneath and in rear of dock. Fig. 1 shows true line to which the steel sheet piling drove in spite of penetrating 25 feet of clay and gravel; fig. 2, method of placing timber fender streak, steel sheet piling ready to receive concrete wall on top; fig. 3, construction completed.



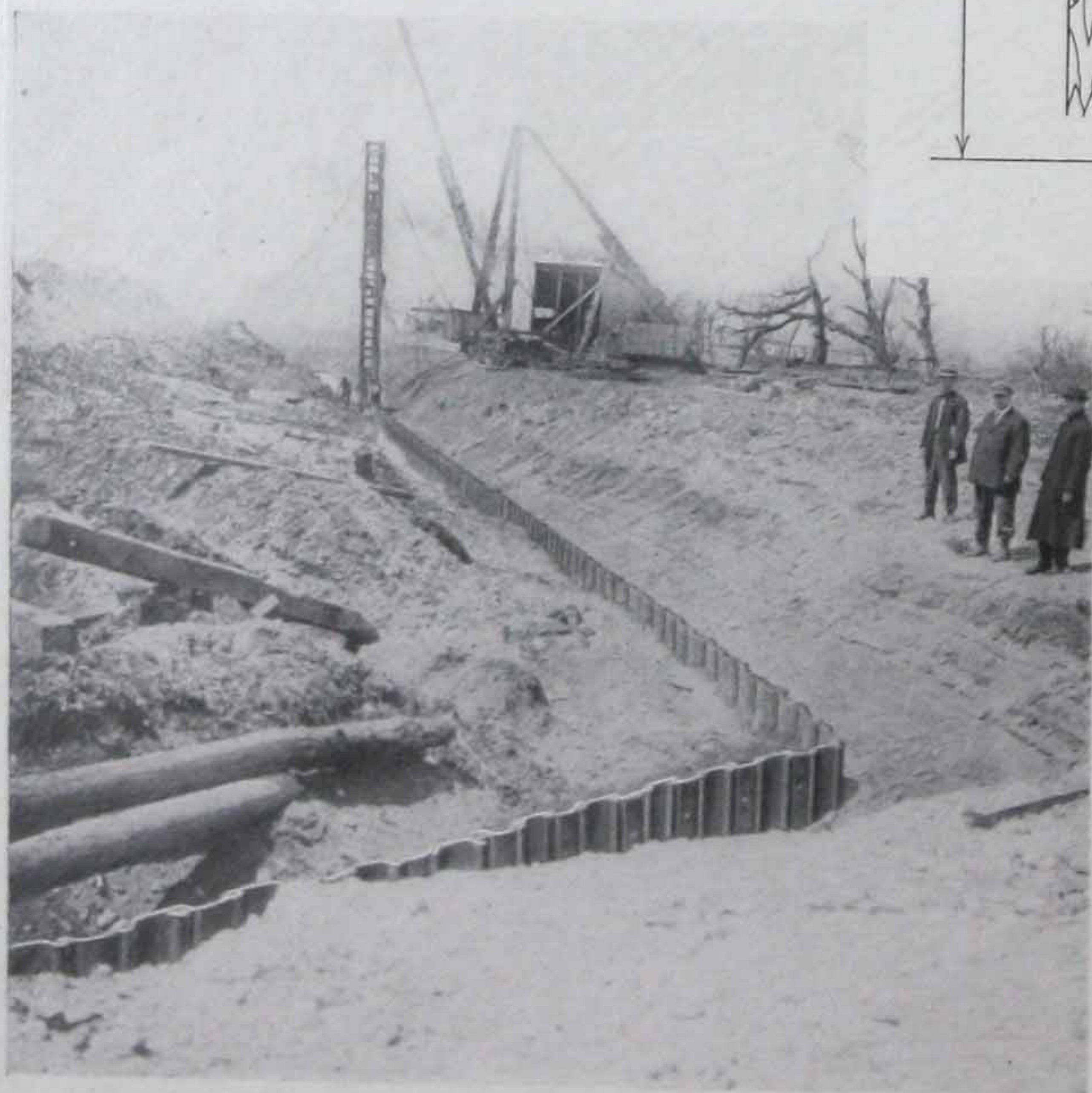
the action of the teredo on timber docks in such localities to become more and more rapid and to extend over more inland territory. Recent Government reports, based on careful investigations, show that in some cases the minimum life of

timber docks under these conditions is only about nine months, and the maximum about two and a half or three years. The use of steel for dock construction in such places must surely become more economical, even considering the question



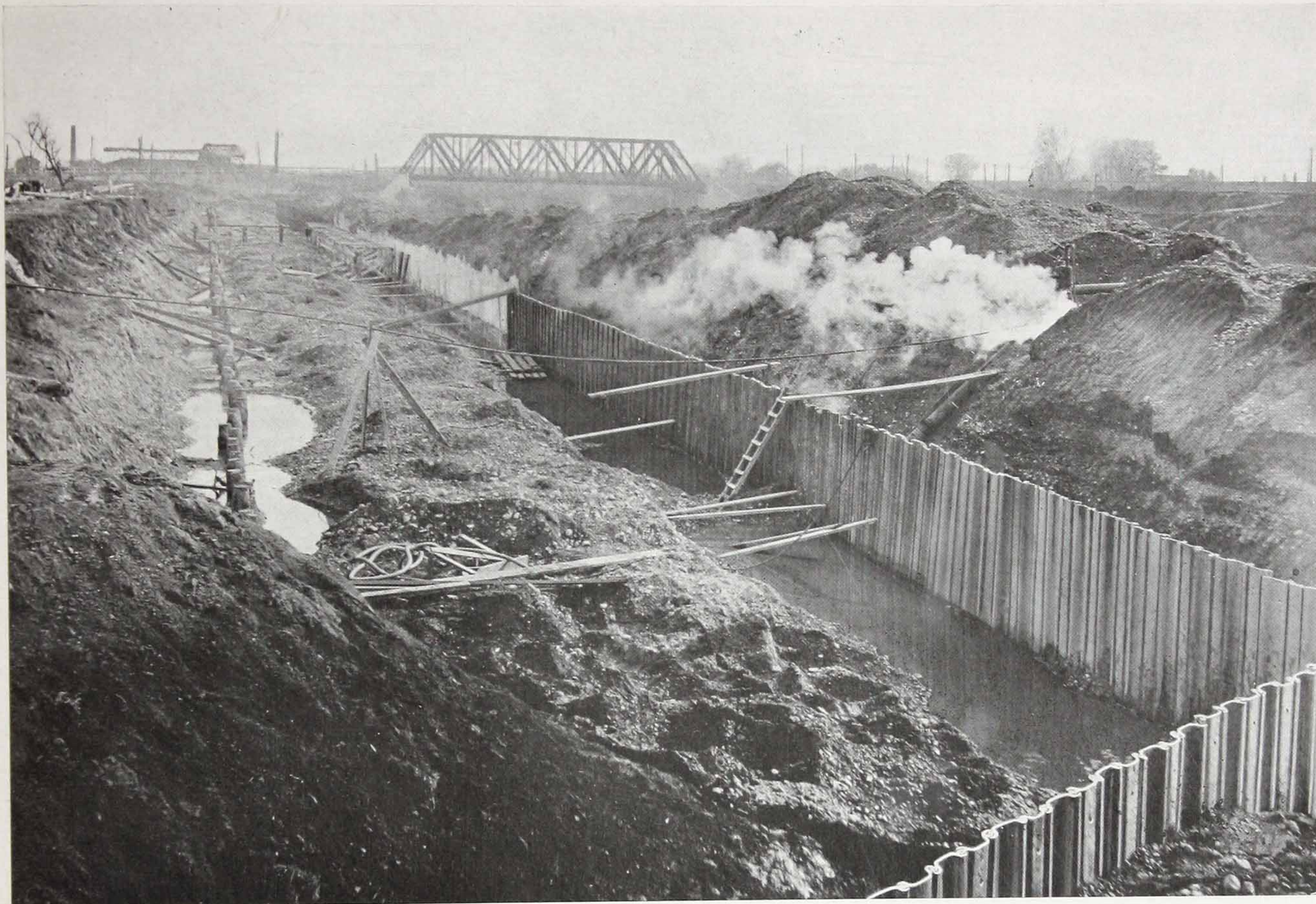
Design of permanent dock wall, as built with Lackawanna 14-inch Arched-Web Steel Sheet Piling, for the Rome, N. Y. Terminal of New York State's \$100,000,000 barge canal.

As indicated, this work involved (1) the excavation of a trench and the driving of a line of Lackawanna Steel Sheet Piling to



a point several feet below canal grade, (2) the encasing of the top eight feet of this steel sheet piling within a narrow wall of concrete, (3) the fastening of the entire bulkhead with large steel tie rods, spaced every seven feet lengthwise of the walls and anchored to a continuous beam of reinforced concrete back of a line of wooden piles driven 35 feet from and parallel to the bulkhead, and (4) the removal to a depth of 12 feet by dredges of material in front of the bulkhead. See also illustrations on pages 25, 60 and 61.

Lackawanna Steel Sheet Piling



Rear view of dock wall for Rome Terminal, New York State Barge Canal, at the time when the concrete top was being molded to the top of the Lackawanna Steel Sheet Piling wall, and when the contractor was ready to place the concrete anchor beam and the tie rods. The amount of excavation shown proved desirable in placing the tie rods, especially as the grade back of the dock was to be reduced, and the four or five feet of material taken off could be used to bring the grade to the right elevation immediately over the tie rods. The earth in front of the wall was afterward dredged away to obtain a depth of 12 feet of water at finished grade. See also illustrations on pages 24, 60 and 61.

of corrosion, for the extra first cost of steel construction would be more than offset by the cost of replacing the timber docks several times during a period representing the life of the steel. Based on careful consideration of these facts, the Jacksonville Port Commission is now using several thousand tons of Lackawanna Steel Sheet Piling in the construction of docks at Jacksonville, Florida, where the teredo is very active.

The same line of reasoning holds good, to a certain extent at least, in comparing the life and cost of ordinary timber docks constructed in waters not subject to the teredo, but where ordinary rotting or decay call for whole or partial

replacement of timber constructions within comparably short periods. It has been proven in fresh water locations also that the life, strength and economy of docks built with steel sheet piling compare more than favorably with docks built of mass concrete walls, concrete walls on timber cribs, concrete walls on timber bearing piles or docks entirely constructed of timber.

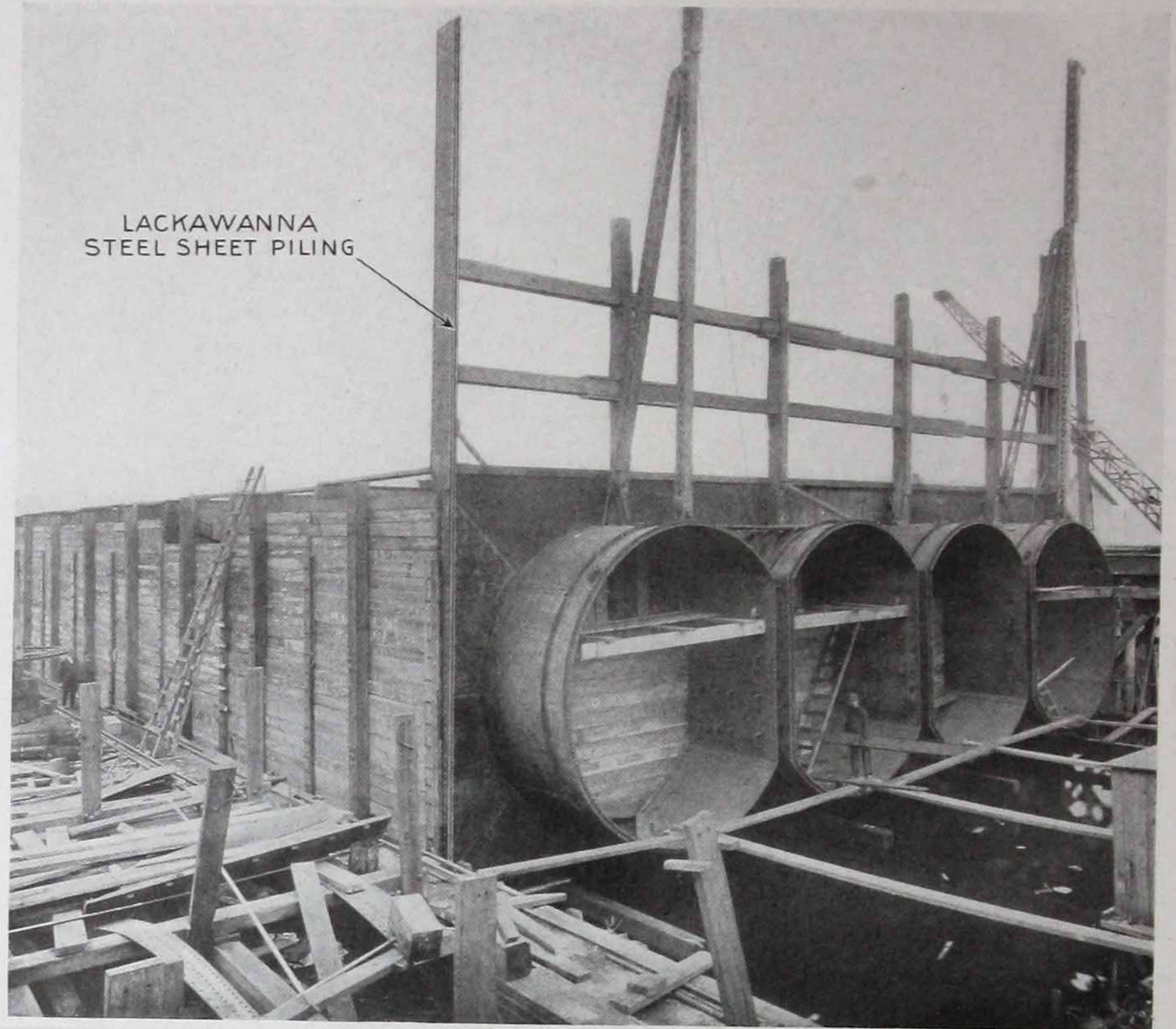
Many thousand tons of Lackawanna Steel Sheet Piling have already been used for dock work, although this form of construction has achieved popularity in America only during the past two years. Illustrations on pages 3, 13, 22 to 25, and 58 to 61 show typical installations.



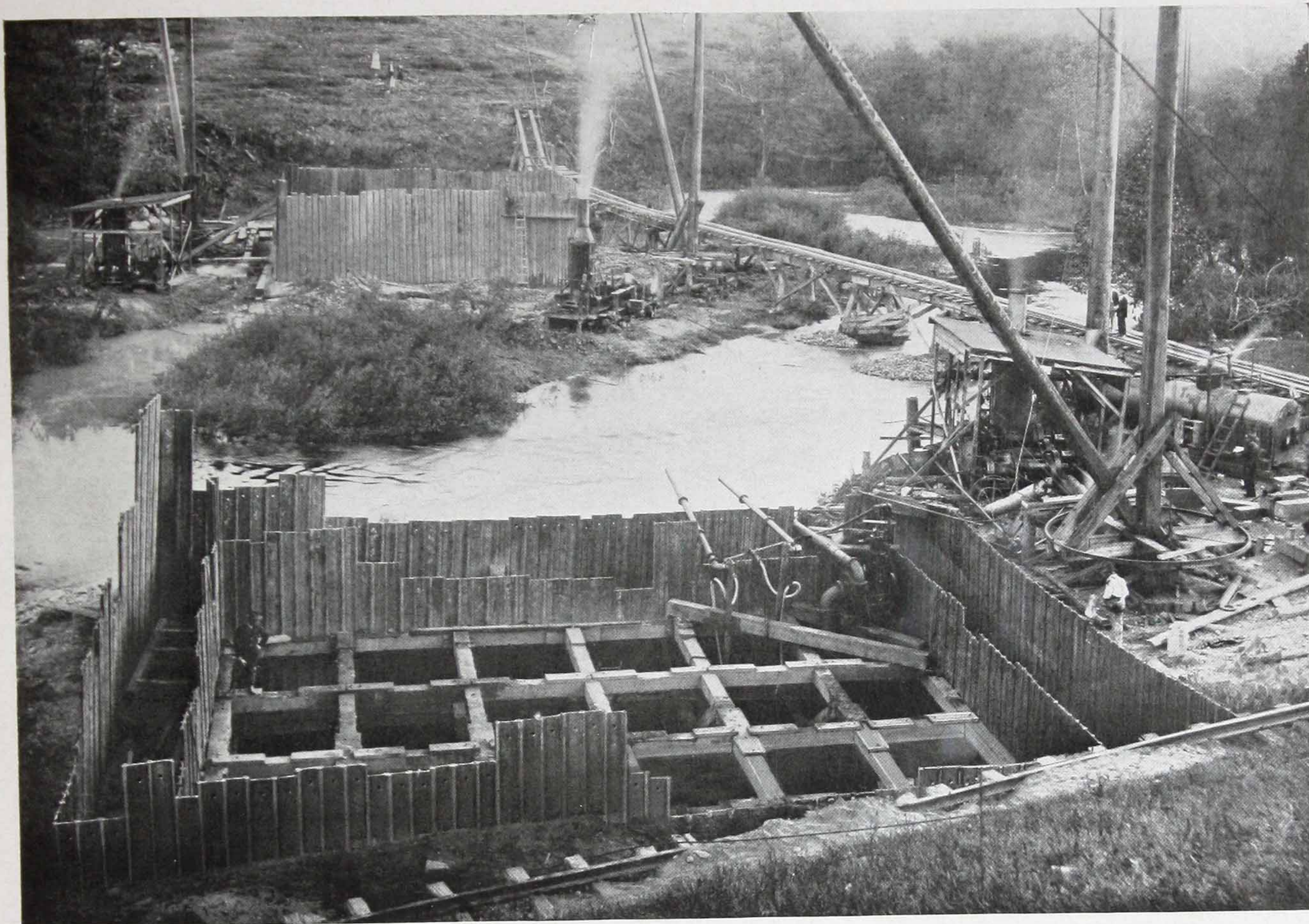
Lackawanna Steel Company



Tubes through which the new Lexington Avenue Subway passes under the Harlem River, New York City. After these tubes were sunk into the river, Lackawanna Steel Sheet Piling cofferdams as shown below were utilized to facilitate connection with the land ends. Split lengths of sheet piling sections attached to each end of the tubes as shown in the upper picture afforded simple means for attaching the cofferdams. An interior view of one of these cofferdams appears on page 35.



Lackawanna Steel Sheet Piling

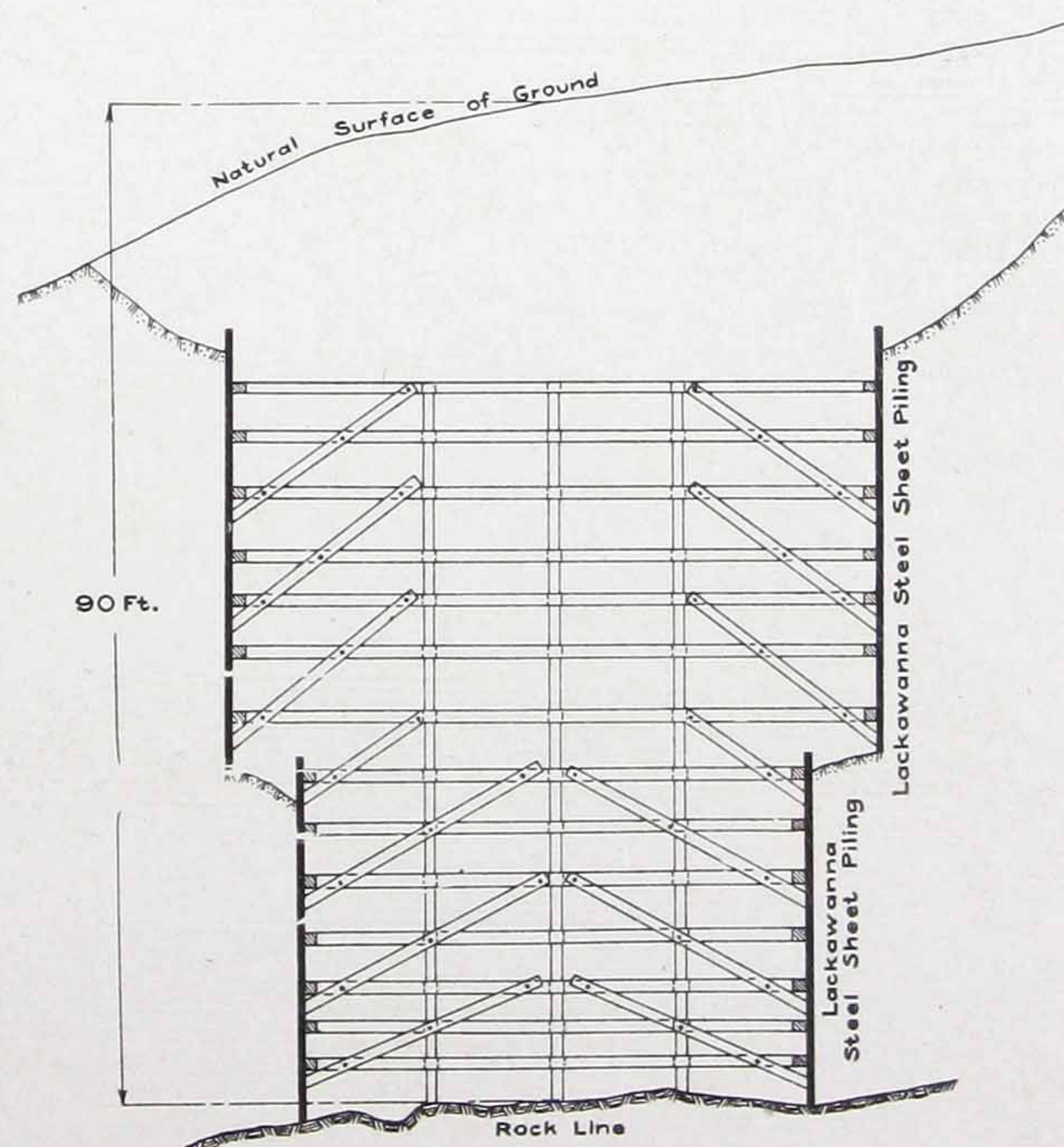


A splendid type of construction for deep foundation work. One of a number of telescope cofferdams of Lackawanna Steel Sheet Piling in which the pier foundations for the Tunkhannock Viaduct, D., L. & W. Railway Cut-Off, were built.

Of 175 Lackawanna Steel Sheet Piles pulled, after this cofferdam had served its purpose, 168 were found to be fit for re-use and were redriven in another cofferdam.

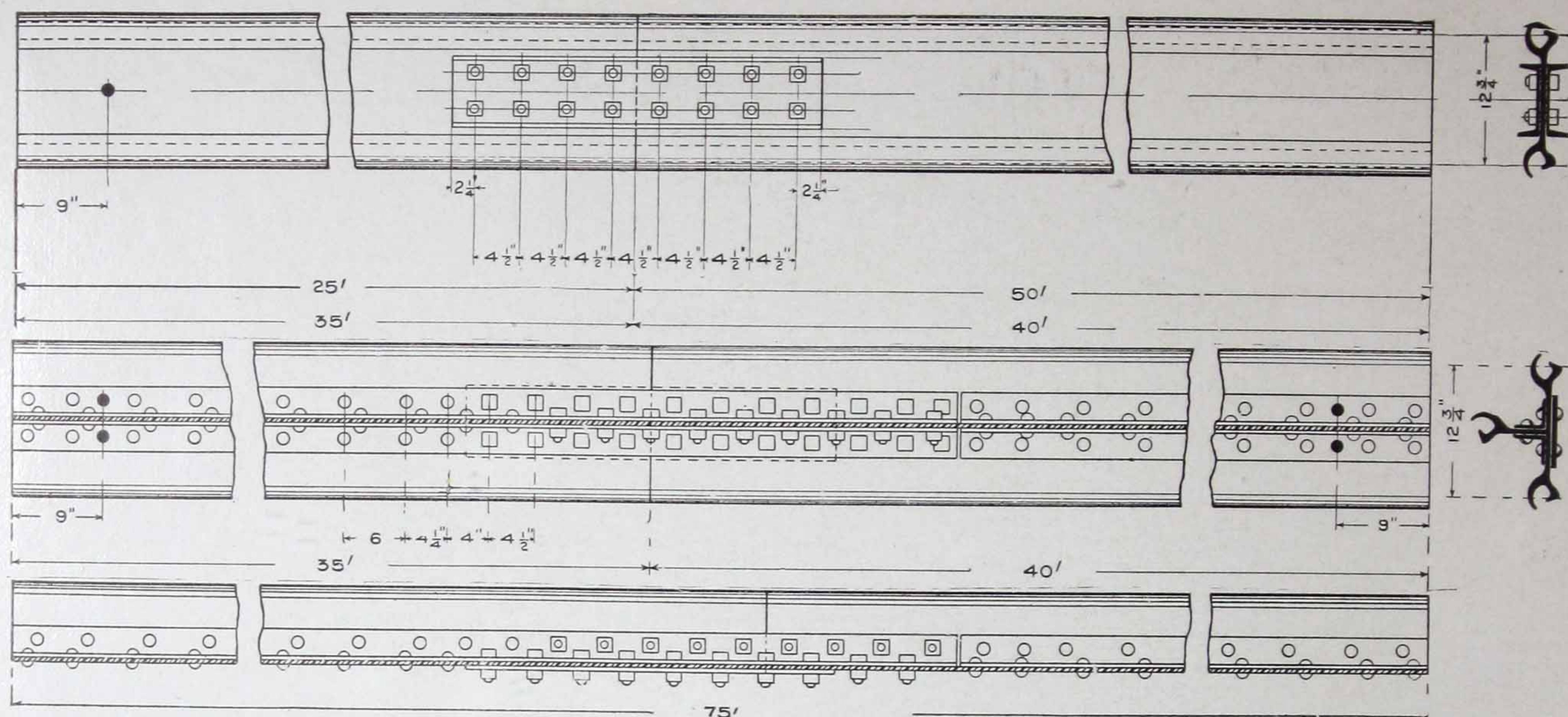
Steel Sheet Piling for deep penetration Spliced lengths

MOST orders for Steel Sheet Piling call for lengths of from 50 feet to 30 feet or shorter. Much longer lengths can be easily rolled and are quite practical, meeting the full requirements of strength, where in case of deep walls, sufficient bracing is used and spaced at proper horizontal planes so as to give safe spans for the piling beams, which latter are supported by the different sets of walings and by the earth at the bottom.

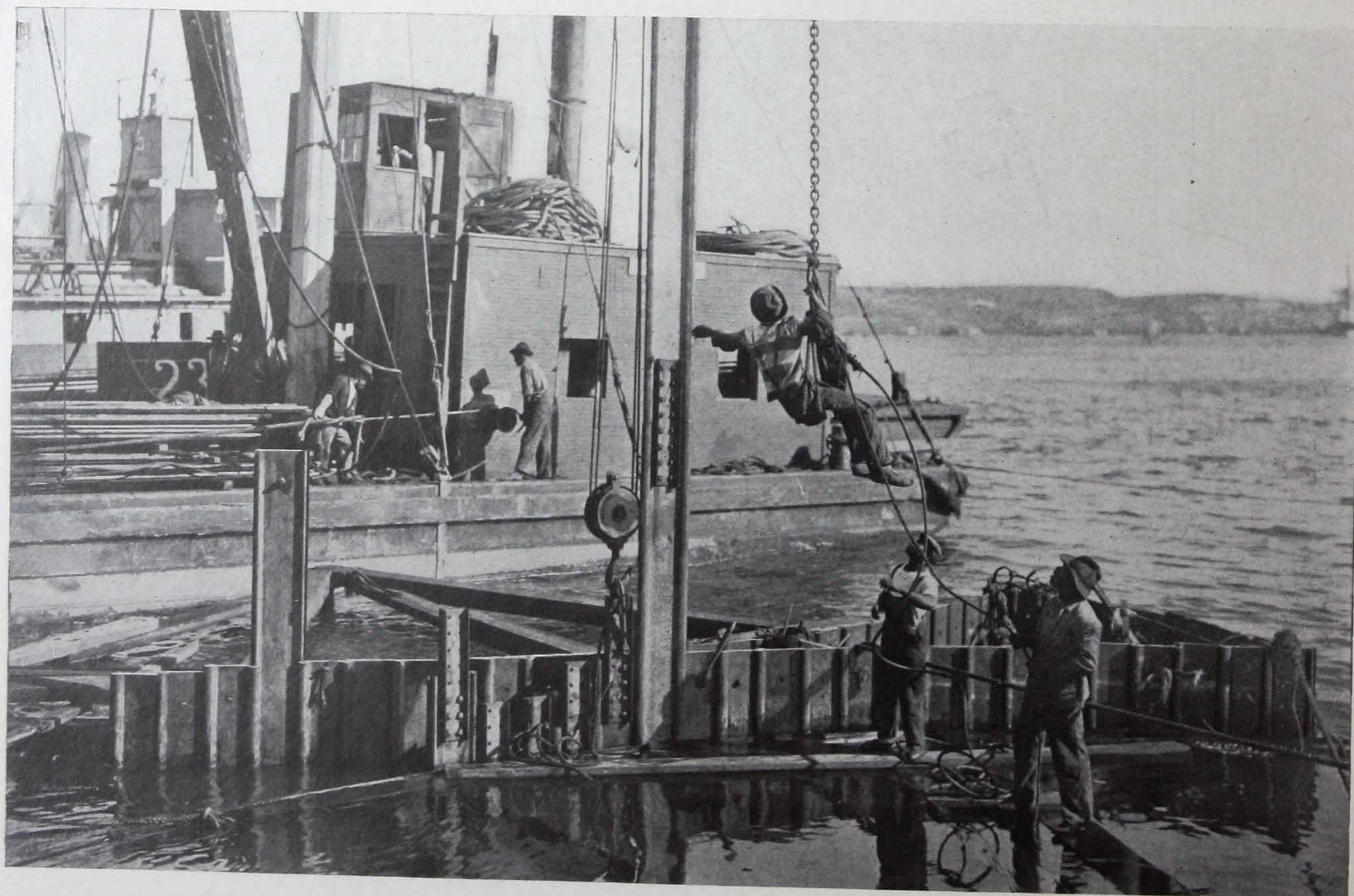




Lackawanna Steel Company



Spliced 75-foot piling lengths and details of splice as used in the Maine Cofferdam.



The method of using a channel bar splice is clearly shown here. The man in the boatswain's chair is being hauled up to set the hammer on the pile just spliced. This view shows conclusively the assistance piles driven give to the one being driven, and the long length of unsupported bar of Lackawanna Steel Sheet Piling that can be driven.

Lackawanna Steel Sheet Piling

Deep foundation work can often be advantageously carried on with short steel sheet piling lengths made into telescoped cofferdams, as in the Tunkhannock viaduct work shown on page 27.

Sometimes in extremely deep work, or for convenience in handling or shipping, a built-up pile, composed of two or more lengths spliced together is desirable. In such case horizontal joints between adjacent piles should be staggered and abutting parts of such joints should be fastened together with splice plates and bolts to form a joint, having lateral strength equal to the rolled section of the pile.

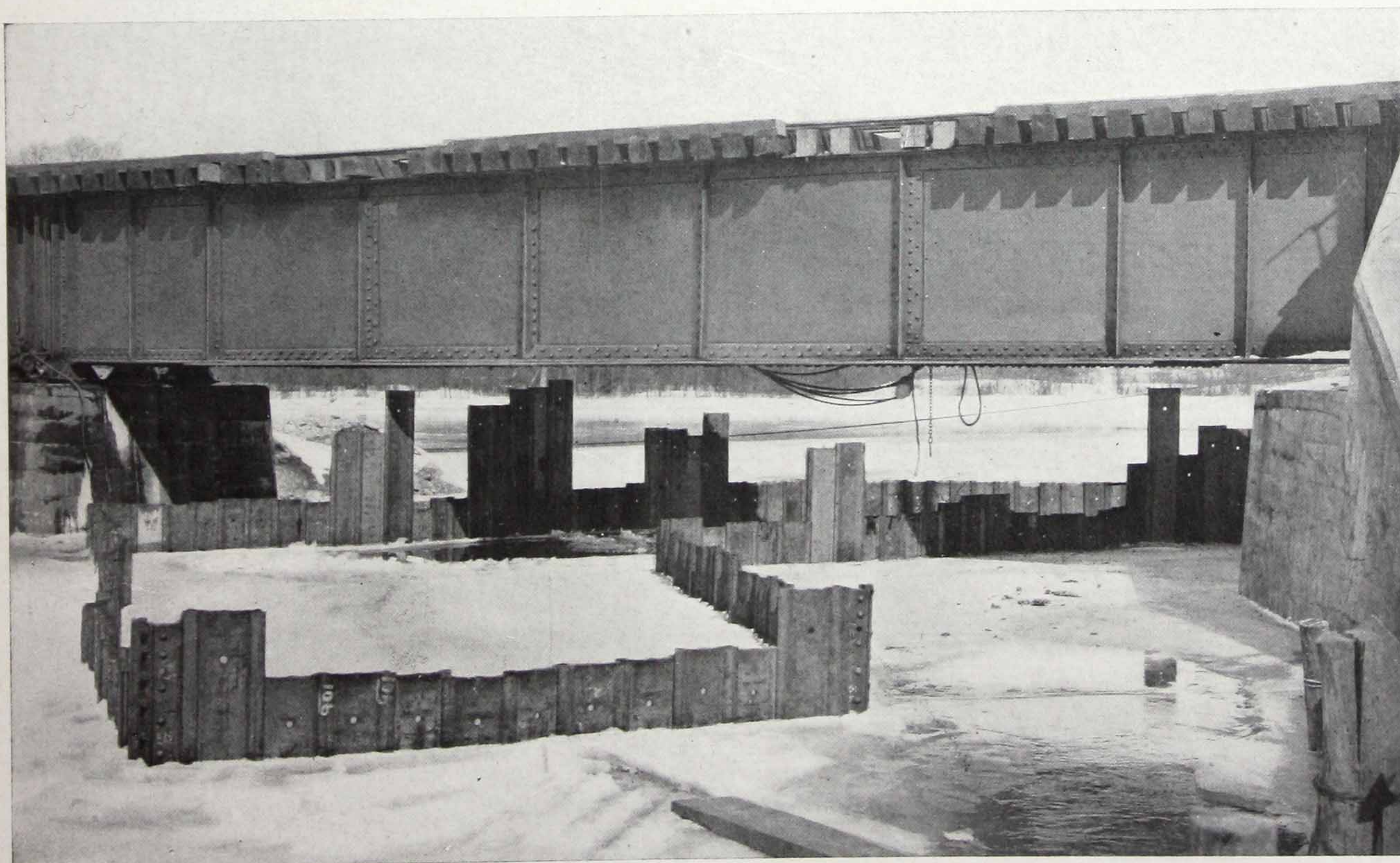
With piles spliced as above, the lower portion can be driven, the splice plates and upper portion bolted on and the entire pile, thus built up, can then be driven to the required penetration; or in cases where the length of the built-up pile, over all, is not excessive, the parts can be first spliced together, handled into the leaders of the driver and driven in one operation.

A typical example of splicing and splice construction is that in the cofferdam for raising the U. S. Battleship Maine from Havana Harbor.

Standard 75-foot lengths could have been furnished for this work, but could not be handled on the ships nor on the work to advantage. Hence the piling was ordered in 25, 35, 40 and 50-foot lengths, a 25-foot top to be spliced to a 50-foot bottom piling section, and a 35-foot top to a 40-foot bottom, these combinations to be driven alternately to break the joints in the wall.

The splice as shown on page 28, consisted of two 7-inch channels, three feet long, weighing $12\frac{1}{4}$ pounds per foot, and having sixteen $\frac{7}{8}$ -inch bolts. The eight bolt holes at the end of each piling bar were made with one punching, as were also the 16 holes in the channels. This splice was found to meet all conditions and have the necessary strength to permit the bottom bar being pulled out of the clay. Other spliced piling sections in the cofferdam for the U. S. S. Maine are shown on page 52.

Spliced Steel Sheet Piling is often used where it is desired to leave the bottom part of the spliced pile permanently in position to protect foundations from erosion from water, etc. In



Where Lackawanna Steel Sheet Piling had to be driven in short spliced lengths to permit installation of the cofferdam under a bridge on the D., L. & W. Railroad.

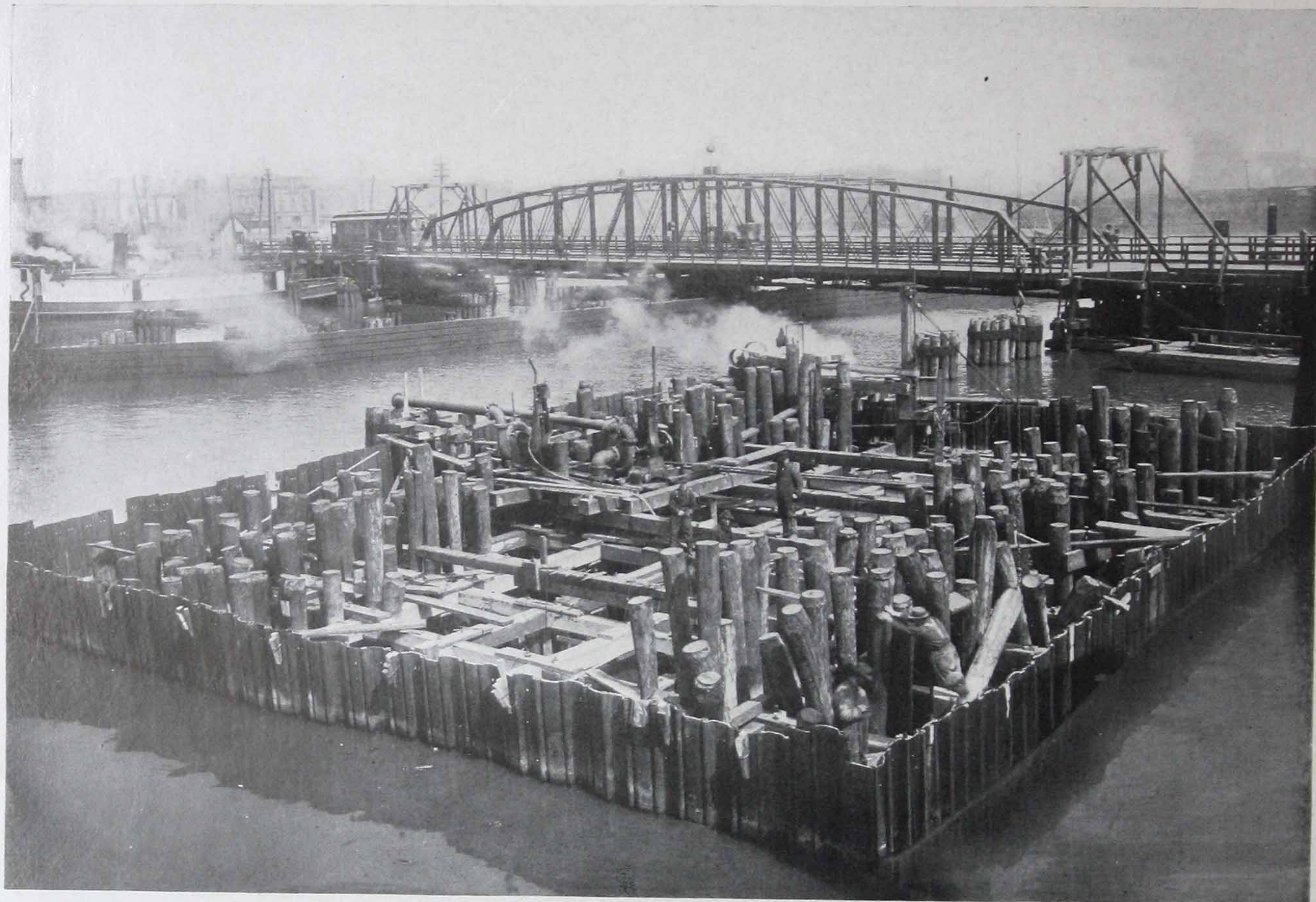


Lackawanna Steel Company



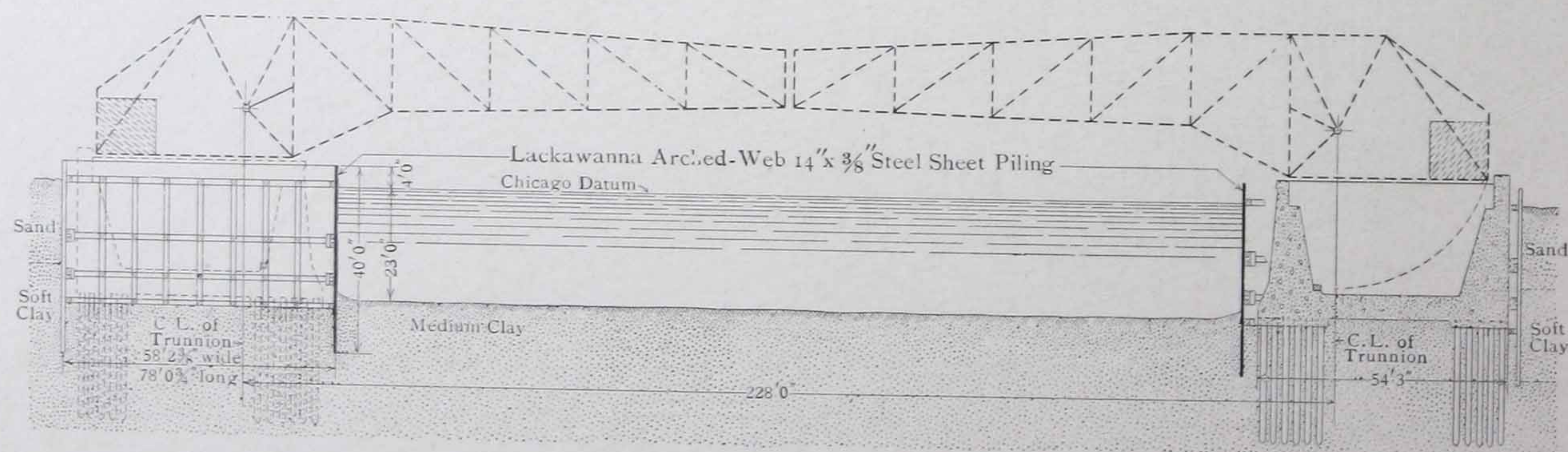
this case the splice can be removed and the upper part of the pile taken away for re-use or for sale as scrap. The Government cofferdam for

King's Bluff Lock, page 8, and the Macon, Dublin & Savannah R. R. cofferdam, page 42, are typical instances of such advantages and savings.



One of the largest (58 by 78-foot) single-wall braced cofferdams ever attempted with steel sheet piling. Built to facilitate construction of one of the abutments for the 92nd Street Bridge, Chicago, as shown in outline below.

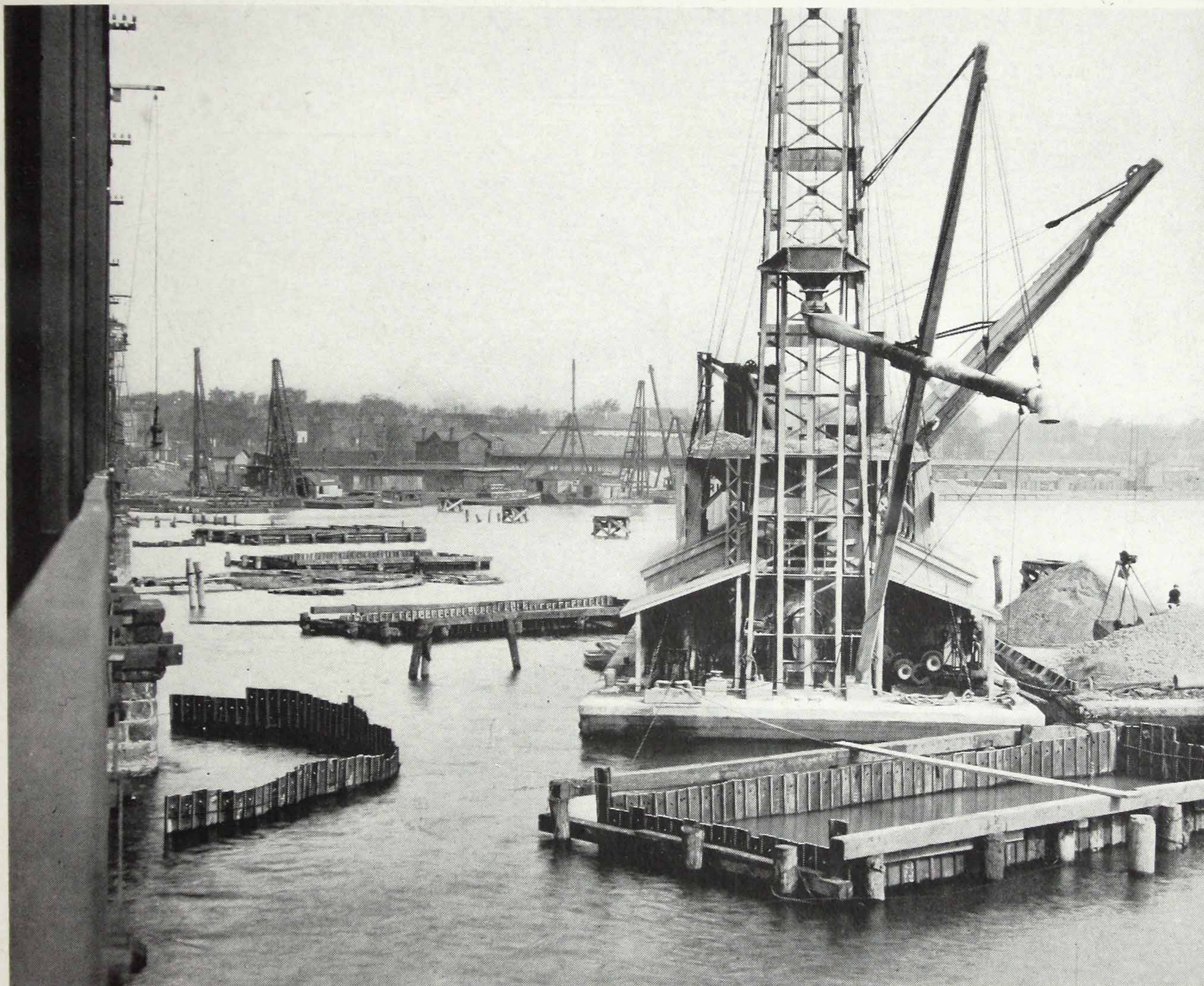
The piling section selected was the Lackawanna 14-inch Arched-Web, because of its relative efficiency in transverse and columnar strength. Although standing in 23 feet of water, this cofferdam was absolutely satisfactory as to watertightness. The sheet piling was afterward pulled, installed in another cofferdam for this same bridge and then utilized again in cofferdam work on another bridge.



Lackawanna Steel Sheet Piling

The use of very short spliced lengths, as in the D. L. & W. R. R. cofferdam shown on page 29 offers a logical solution when the use of steel sheet

piling is desirable, but where limited head room under sidewalks, bridges, viaducts, etc., does not permit the driving of full-length piling sections.



Lackawanna Steel Sheet Piling cofferdams which enabled the Pennsylvania Railroad to complete its new bridge across the Maumee River at Toledo, Ohio, in the record time of eight months when ordinarily twice that time would be required.

The pier foundations were constructed by the wet method, the Lackawanna Steel Sheet Piling cofferdams being used to retain 2-in. limestone at the bottom of the excavations and also serving to surround the forms for the concrete in the pier fenders.

The new bridge is parallel and close to an older bridge which has shallower foundations that needed protection. This protection was afforded by 45-foot lengths of Lackawanna Steel Sheet Piling driven close to the old piers and in the shape of a half-moon, as shown at the lower left in the picture. All strain was thus taken from the masonry and the surrounding material held in place.



Steel Sheet Piling superior to wood sheet piling

NEARLY all recognize the merits of steel sheet piling and its great advantage over the older method of using wood. Timber sheet piling can do but part of the work of

Lackawanna Steel Sheet Piling and that only where short lengths are practical and where the driving is not difficult, as, on an average, only one-third of the wood is available for a second installation. Steel is usually better even on comparatively easy work because steel provides every strength element of tongue and grooved



Trench walls of Lackawanna Steel Sheet Piling driven by Prang & Vanderweele Bros. in constructing a 6-foot trunk sewer of Amco Segment Block in Ludington, Mich. The trench was excavated by clam-shell bucket to a depth of 16 feet, and the walls sustained by three horizontal rows of waling with extension cross braces. See interior view on opposite page.

Lackawanna Steel Sheet Piling



Interior view of trench shown on opposite page. Note particularly the straightness of the Lackawanna Steel Sheet Piling walls.



7-inch by $\frac{1}{4}$ -inch Lackawanna Straight-Web Steel Sheet Piling used for trench work by the Des Moines (Iowa) Water Company. The trench is enclosed in cofferdams about 50 feet in length, and the movable machine on the right in the background is arranged to drive both side walls and also the traverse walls. The sheet piling is assembled in wall form before driving.

Lackawanna Steel Sheet Piling

wooden piling and a joint-strength that is entirely absent with wood, while the increased transverse strength greatly reduces the amount of bracing required. The growing scarcity and constantly increasing cost of timber is also a factor to be considered. The small thin section of Lackawanna Steel Sheet Piling (See page 16), made especially as a substitute for timber in sewer, trench and small cofferdam work, possesses every advantage without the disadvantages of timber. It can be made into a strong watertight wall of single thickness, is decidedly easier to drive and pull and can be used repeatedly. With

steel the driving blows, which, with wooden piling, spend themselves to a great extent in mashing the pile, go almost entirely into useful work; there is no danger of split sections, either at or between the joints, and thus no chance for bad leaks and weak spots in the wall. After a few re-installations of the steel, it will have cost no more than the wood, and further use reduces its cost, per square foot, far below that of the timber sheeting.

The final value of the steel sheet piling as scrap still further reduces the ratio of cost between the wood and steel.



Lackawanna Steel Sheet Piling cofferdam driven to bedrock (58 feet below surface) and with preliminary excavation completed to a depth of 15 feet, Manhattan approach to Harlem River Tubes, New York City. Exterior views of this work are shown on page 26.



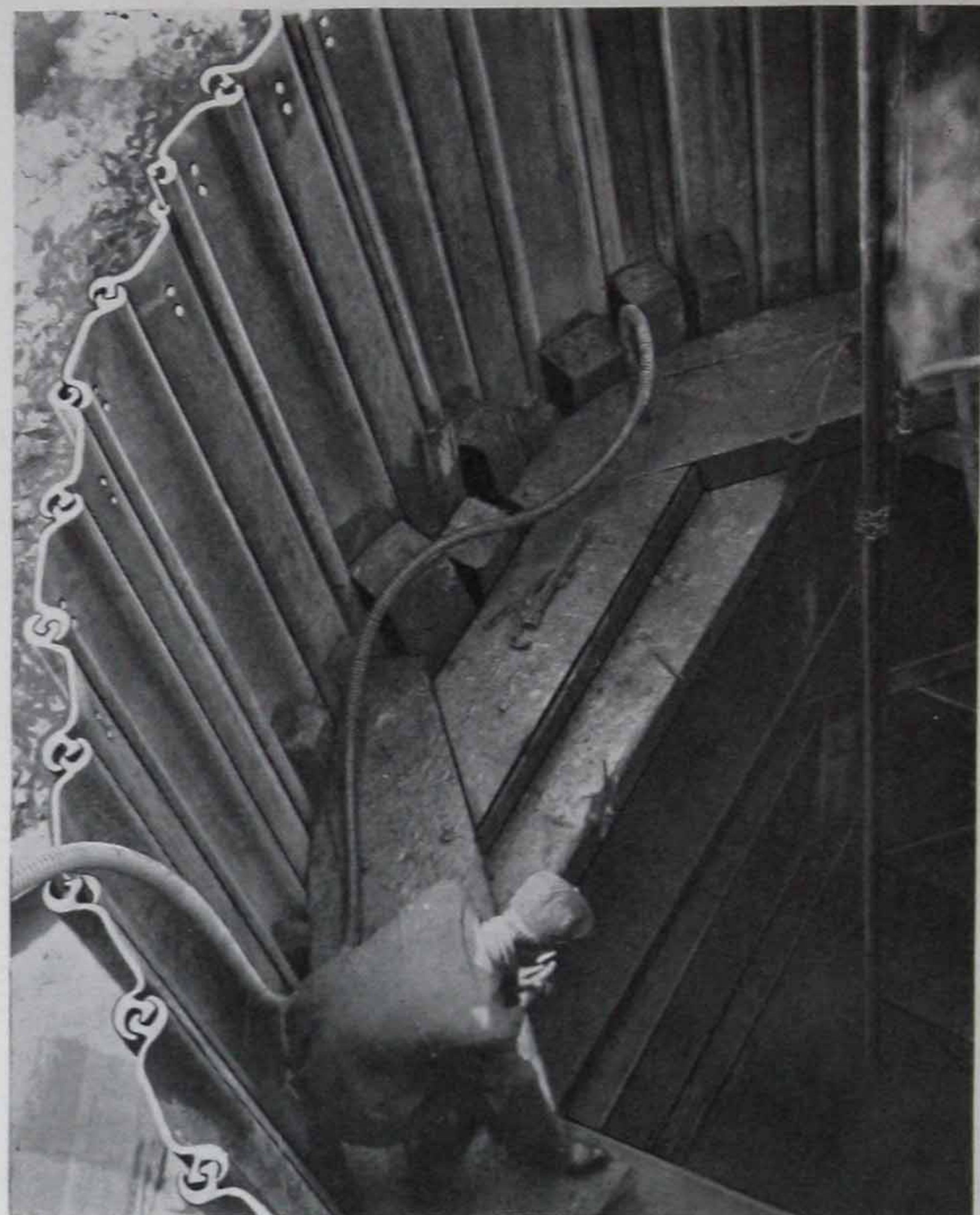
Bracing the Lackawanna Steel Sheet Piling caissons against exterior pressure, Lake Shore R. R. Bridge over Buffalo River.

The picture opposite shows the inside of one of eight Lackawanna Steel Sheet Piling caissons, excavated, braced, pumped out and ready to receive the concrete.

The material in each caisson was excavated under water by an orange-peel bucket swung from a car-mounted revolving derrick. About five feet of hardpan just above bedrock was left temporarily for a bottom seal and the caisson braced inside to prevent collapse on the removal of the water.

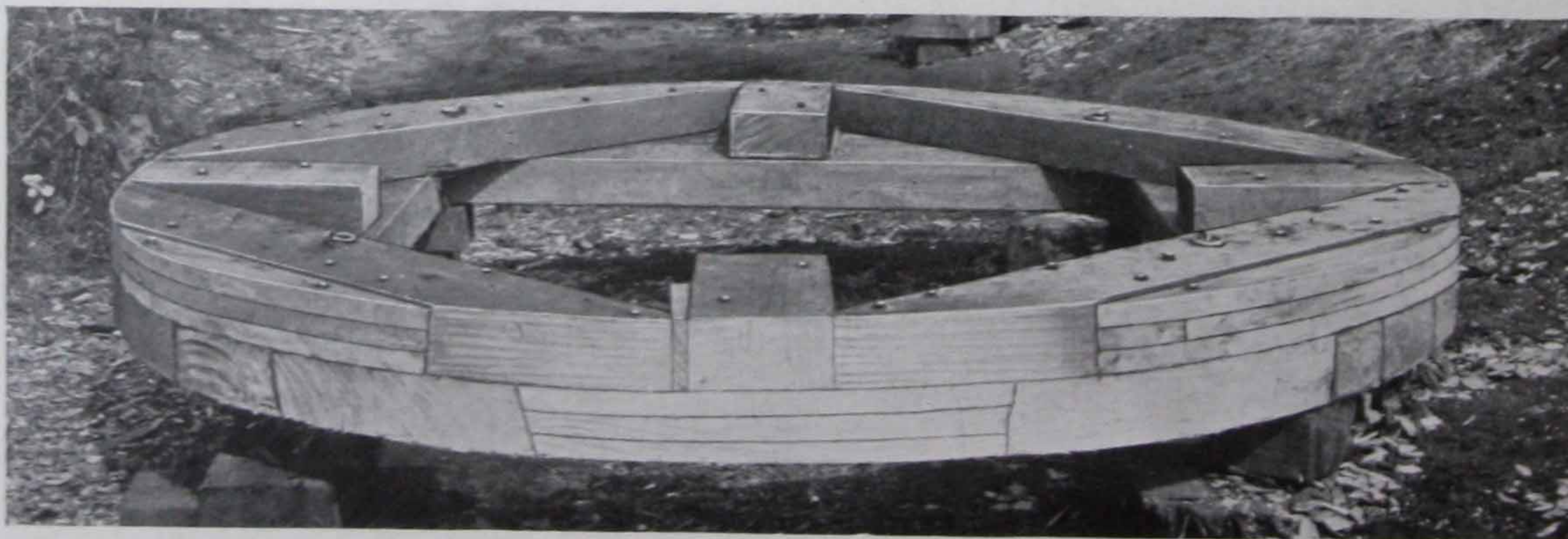
The bracing consisted of heavy circular rings of timber made up of two courses of 9-inch by 18-inch stringers, bolted together as shown in the picture below. The frames had a central opening 10 feet 6 inches square and hook eyes were placed at the corners of the square for handling.

The frames were placed in the cylinders by the revolving derrick, large vertical posts, about 5 feet high and securely held by diagonal bracing, having first been attached to the top of the first one. A second ring or frame was then laid on top of the posts of the first one and both were driven down by the pile driver. This procedure was repeated until five frames had been placed, the lowest being about 5 feet above bedrock. The cylinder was then pumped out and the remaining material down to bedrock removed in large buckets. Wedges

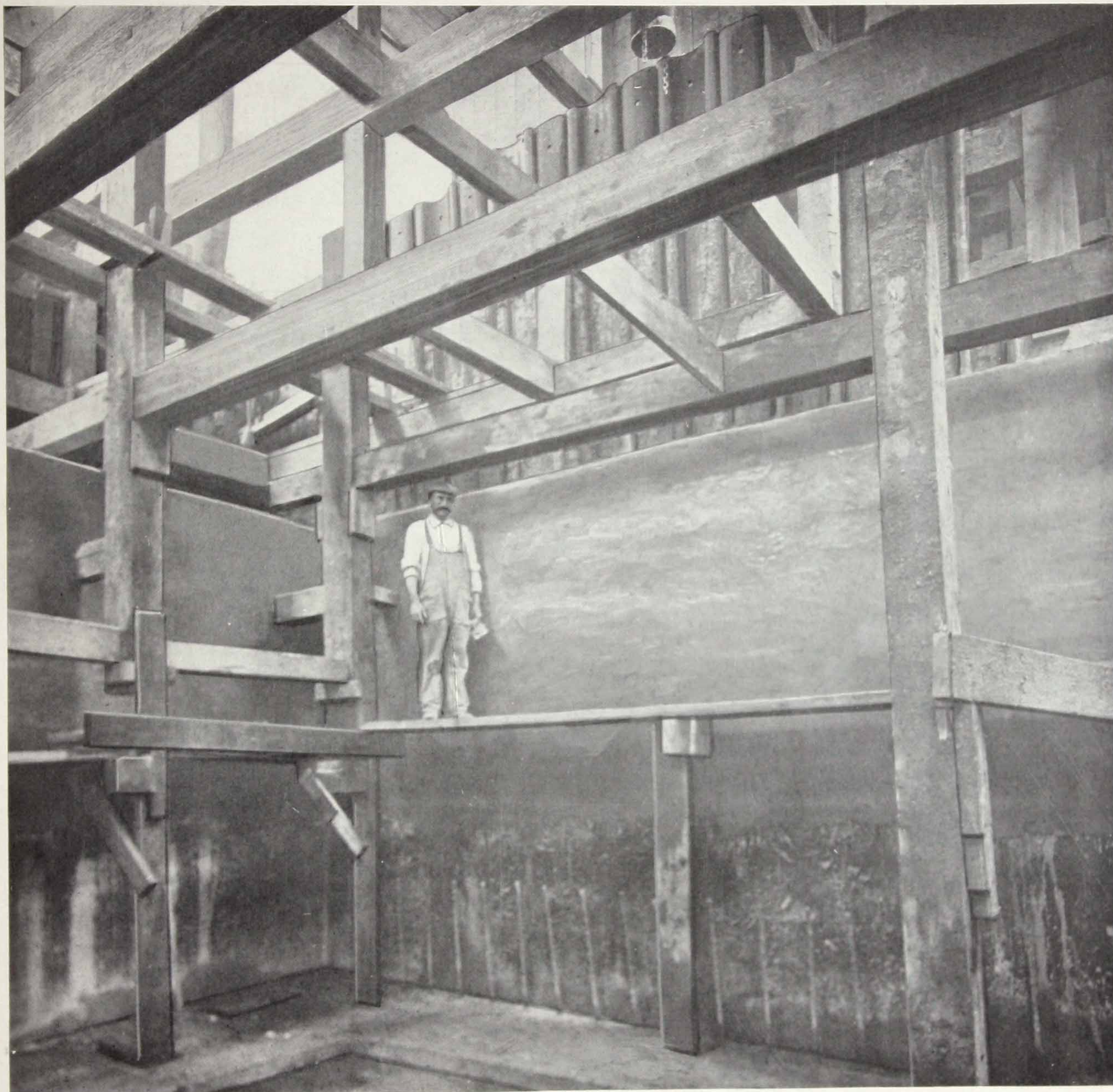


as shown in the picture were inserted between the bracing forms and piling wherever necessary to assure more solid bearing of the piles against the forms. Octagonal forms resting on the bedrock were then built inside the cylinders and the concrete dumped in through vertical chutes reaching to the bottom.

The watertightness and extreme strength of the Lackawanna Steel Sheet Piling were demonstrated in every cylinder.



Lackawanna Steel Sheet Piling



Interior view of subway work in Boston, Mass., where Lackawanna 14-inch Arched-Web Steel Sheet Piling was driven in 35-foot lengths to retain adjacent streets and buildings.

Bracing of cofferdam and sheet piling walls

THIS is a subject which cannot be generalized. Each piece of work requires different treatment, depending upon type and method of construction, character of upper and lower materials penetrated, section and length of sheet pile used, inside width of the cofferdam, and many other conditions, some of which can be

considered only as uncovered during construction.

To give any clear statement covering all bracing problems would require a good-sized volume. Each case can be best solved by individual design and calculation as a separate study. However, we show on pages 27, 30, 32 to 39, 44 and 57 a number of typically-braced sheet piling structures and have records of applications of every imaginable kind of bracing. As in other piling problems, our engineering department is always



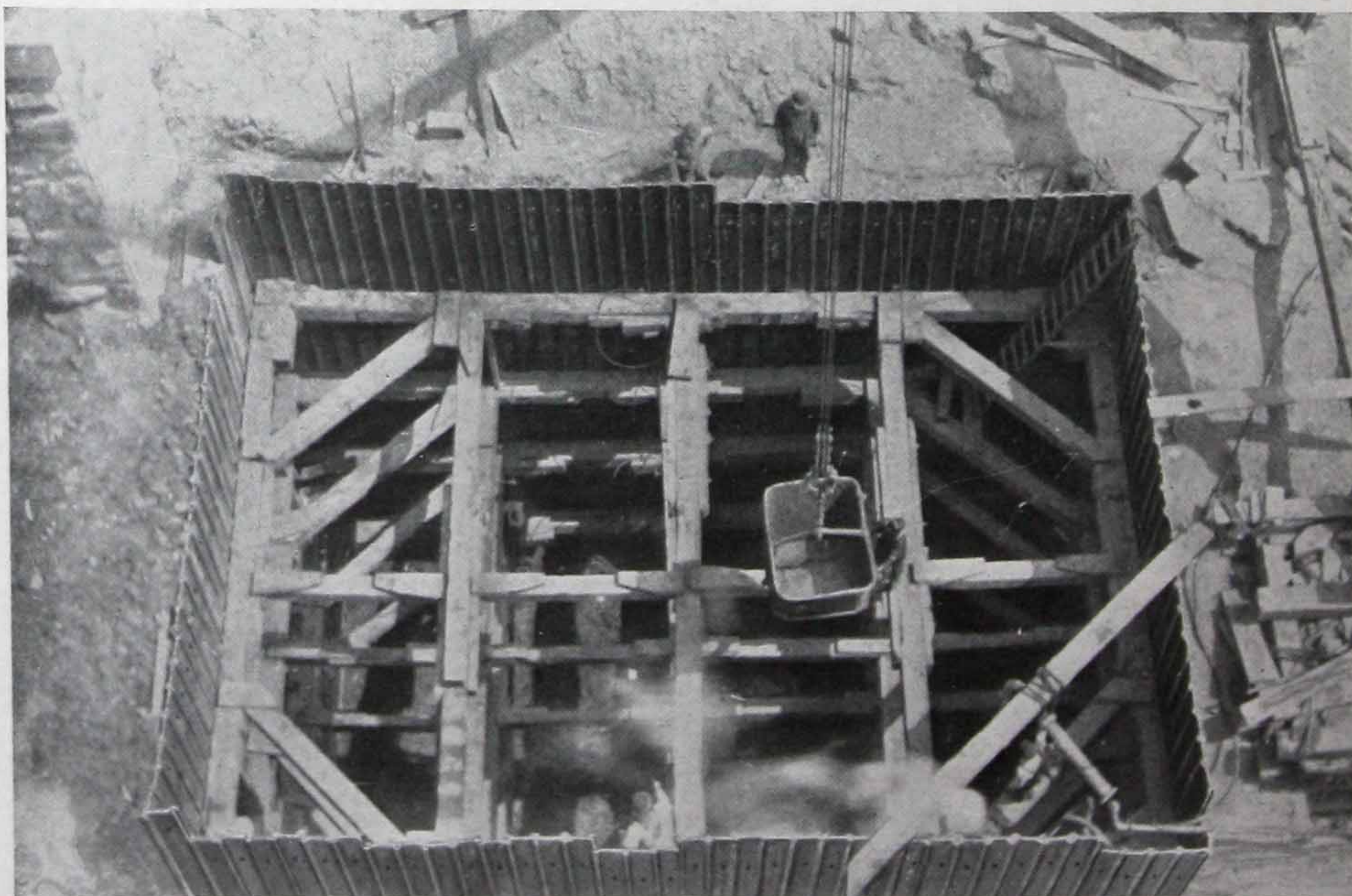
A system of radial bracing as used in circular cofferdams. Some time ago a Lackawanna Steel Sheet Piling Cofferdam was driven by Snare & Triest, N. Y., to enclose one of the pier foundation sites of the Bridge Street Bridge over the Passaic River, Newark, N. J.

The piling in that cofferdam when pulled was redriven to form the circular cofferdam (48 feet in diameter) for the center pier of the same bridge, as shown herewith. This piling, in 35-foot lengths, drove as well the second time as the first, notwithstanding the fact that the materials penetrated were so hard as to require subsequent hand excavation. As the second cofferdam stood in 20 feet of water, oakum was driven into the piling joints from the top by steel rods to insure watertightness.

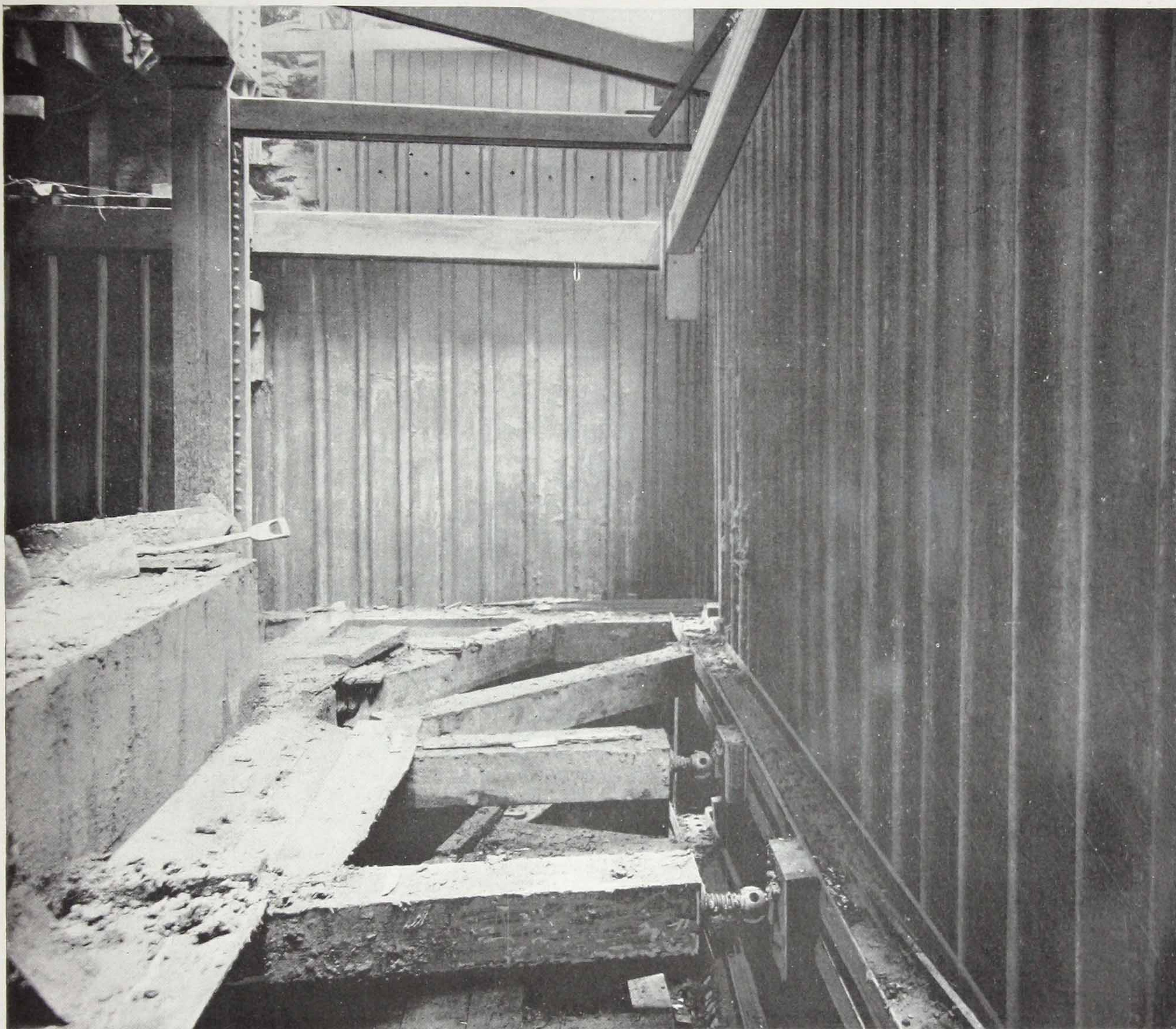
An unexpected strata of quicksand necessitated driving the piling farther, which was done with a 5,000-pound McKiernan-Terry steam hammer suspended from a boom on a derrick boat. The final driving, although subsequent to caulking the joints, did not impair the watertightness of the piling, but the top of the cofferdam had to be brought above high water by the addition of 1-inch wooden boards with canvas outside.

Upon completing excavation, the Lackawanna Sheet Piling was found to be in excellent condition, and at no time was there trouble from water penetrating.

A good arrangement of bracing for rectangular cofferdams. Note the extreme regularity with which the Lackawanna Steel Sheet Piling has been driven—this in spite of encountering boulders and penetration at the bottom through 12 to 18 inches of shale rock. This cofferdam was driven to facilitate the construction of one of the abutments of the new P. & R. railroad bridge at Yardley, Pa.



Lackawanna Steel Sheet Piling



Lackawanna Steel Sheet Piling wall driven by James Black Masonry & Contracting Co. in connection with excavation for outside walls of the power-house of the Kingston Investment Co., St. Louis. The steel sheet piling was completely assembled in advance and driven to required depth before excavation, was later braced against unexcavated material, and the structural steel of the building was erected before the outside walls were built. Note plumbness and straight line of steel sheet piling walls, the use of I-beams for waling, and the long piling lengths between braces.

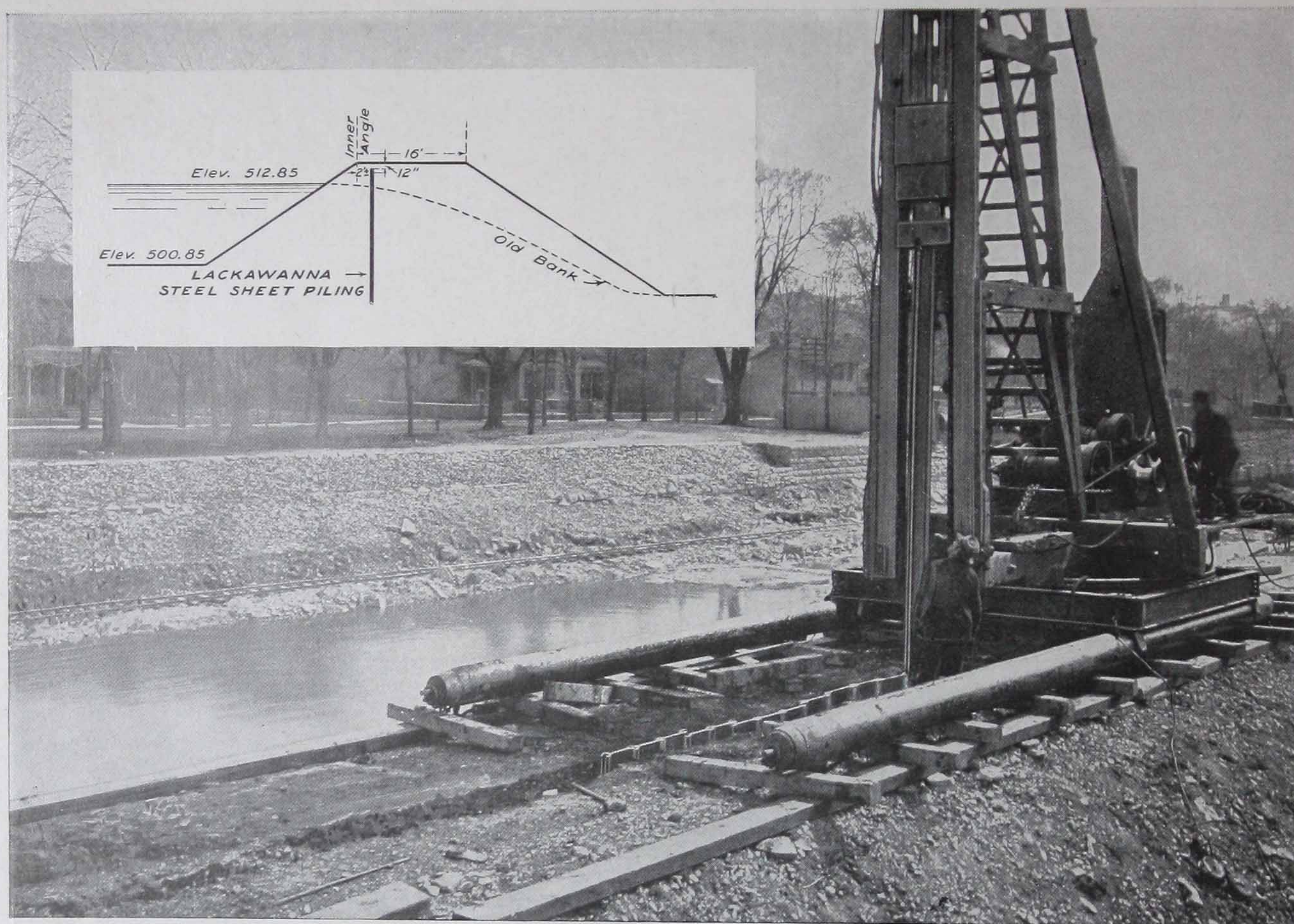
ready to offer practical suggestions on bracing.

Impermeability of interlocked joints

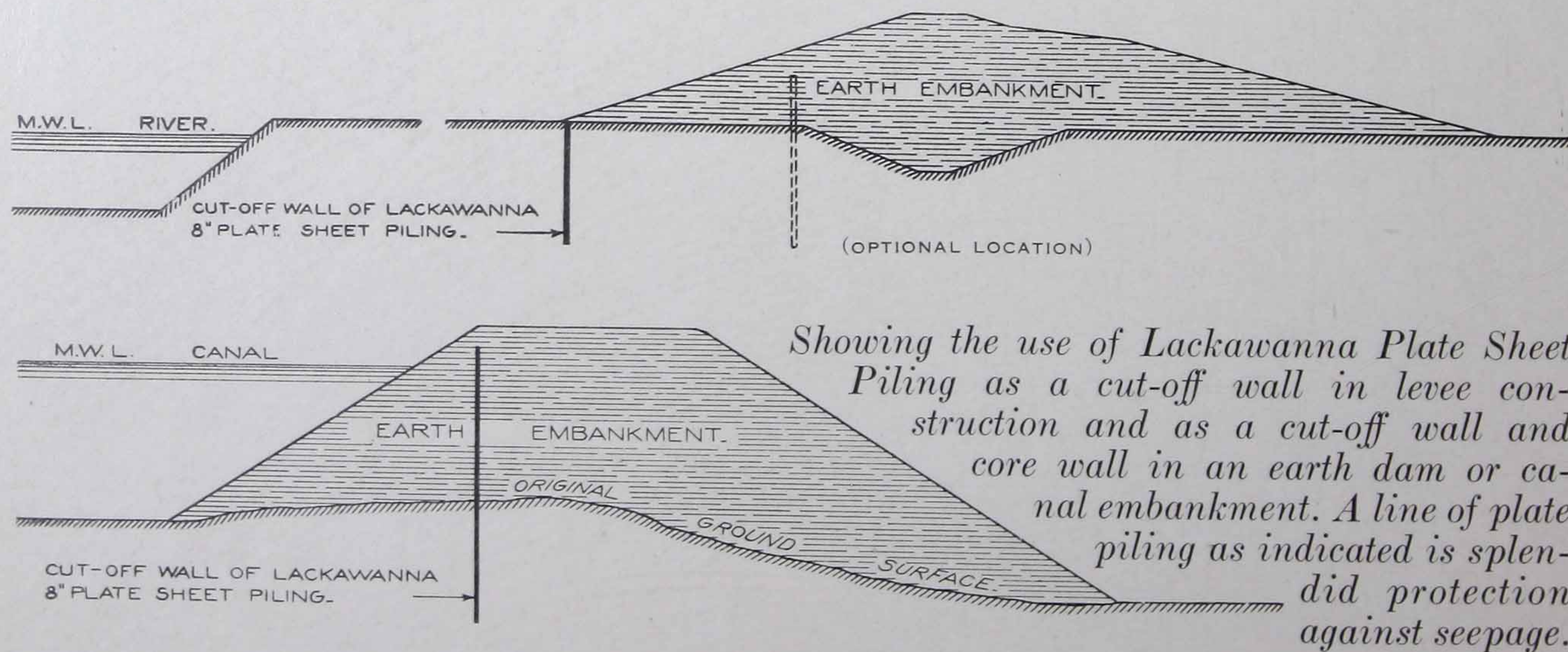
RESISTANCE against the passage of water, or quicksand, through the interlocked joints of a steel sheet piling wall is of great importance, and usually an absolute essential.

The joint, however, must be so constructed, and the contact of the interlocking parts must be such, that easy driving and pulling of the piling can be obtained without undue friction.

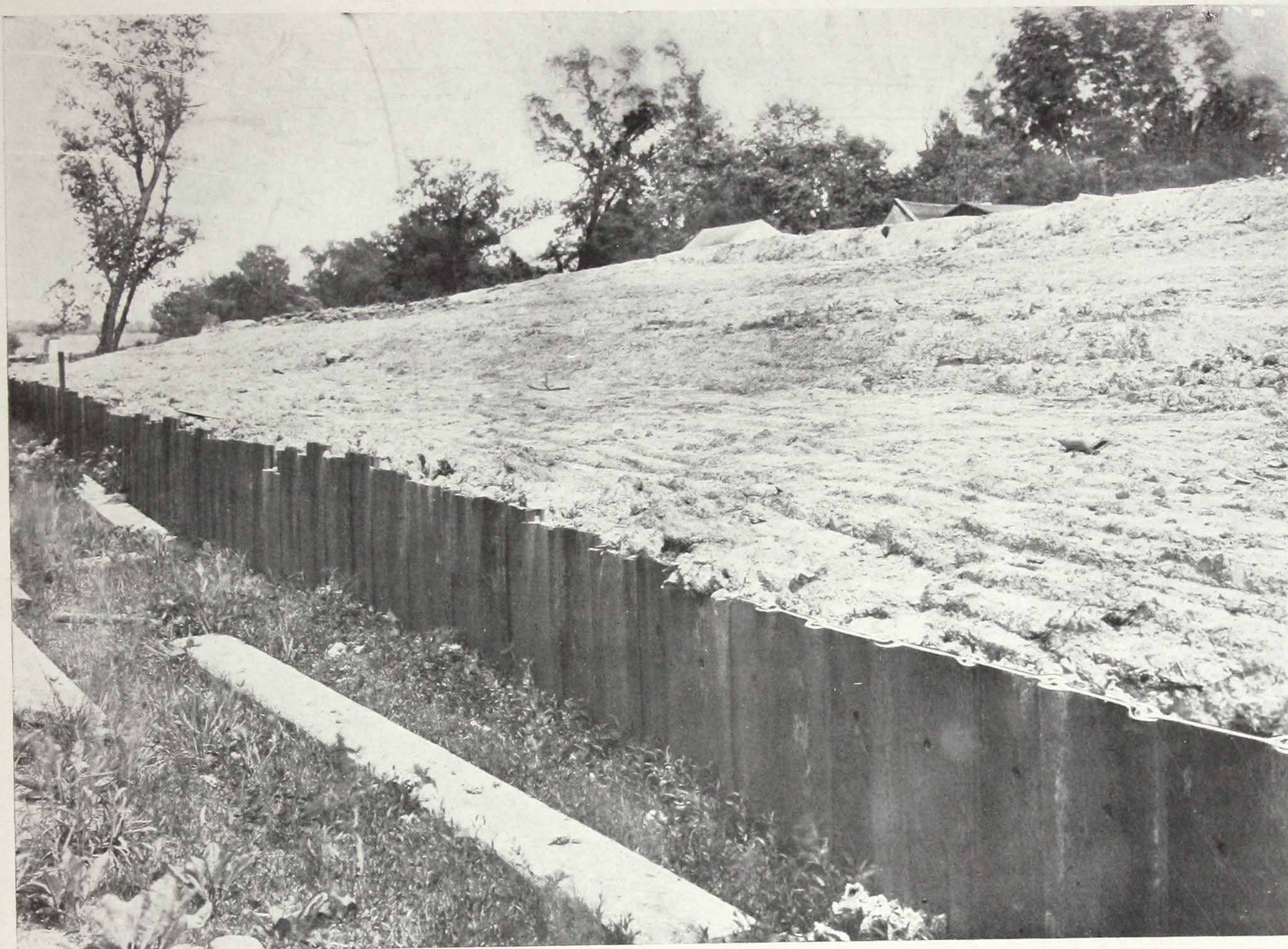
Accuracy in rolling the piling sections, the three points of contact between the interlocking parts, and the two interior sealing pockets within the joint, all go to make Lackawanna Steel Sheet



Core wall and cut-off wall of Lackawanna Steel Sheet Piling to prevent seepage through and under banks, New York State Barge Canal. The Sheet Piling absolutely prevents any break that might seriously inconvenience shipping, cause flood or deposit silt on adjoining lands. Over 11,000 tons of Lackawanna Steel Sheet Piling already used in this work.



Lackawanna Steel Sheet Piling



An instance of what Lackawanna Steel Sheet Piling is doing in levee work on the Mississippi. In making the new East St. Louis levee effective, the outlet of Cahokia Creek into the Mississippi had to be shifted and the levee embankment built across the old channel. The foundation of the new levee at this point, during flood periods, if unprotected, would be subjected to a cutting and undermining action from the current, the original soil under the old creek channel being of such a nature that there was a possibility of seepage under the new embankment.

A revetment and sub-curtain wall of Lackawanna Steel Sheet Piling, part of which shows above ground, was therefore driven across the old creek channel at the foot of the levee embankment and on the river side to prevent such action.

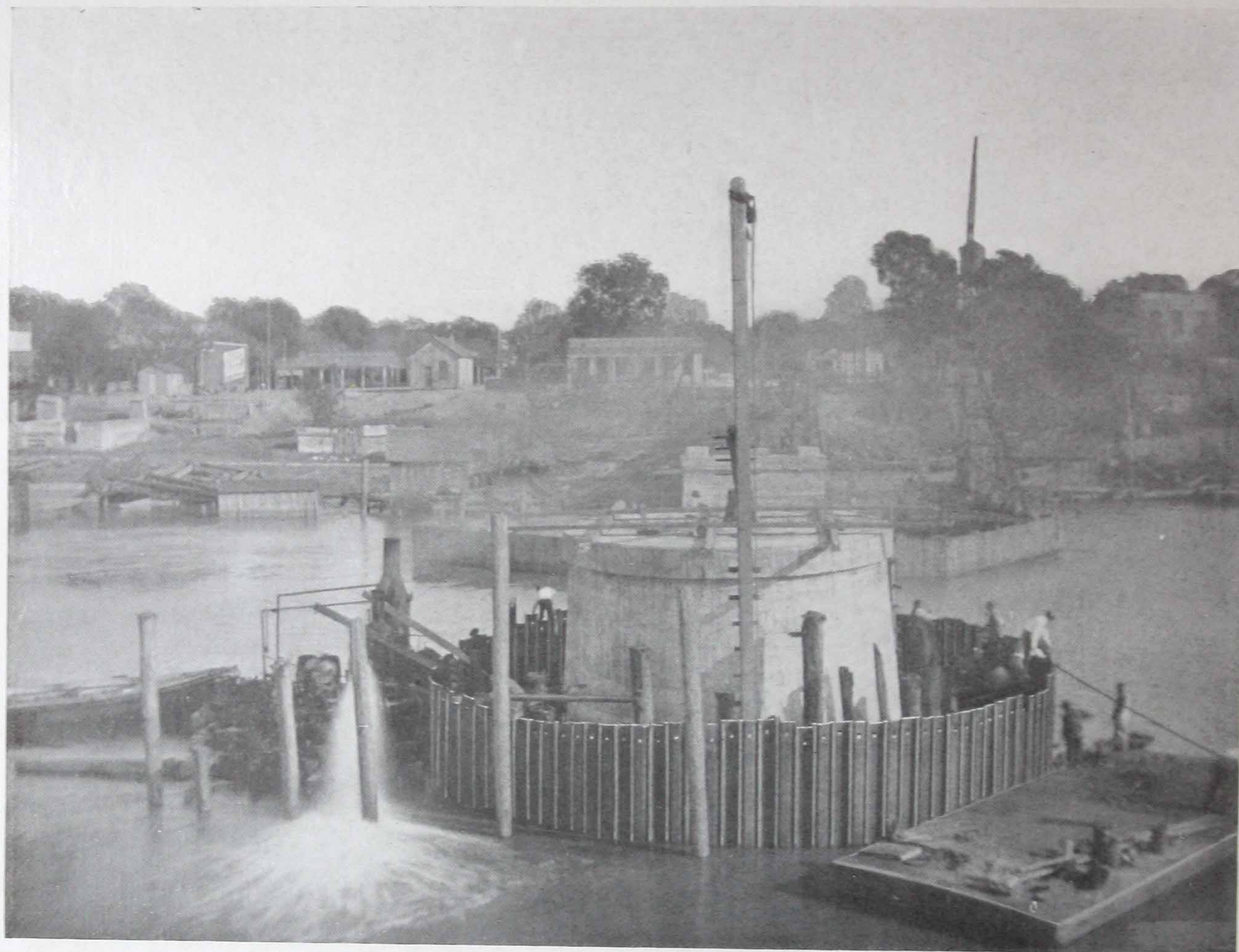
The upper part of this sheet piling wall acts as a permanent revetment to protect the base of the levee; the lower part checks seepage and undermining.

Piling pre-eminent in this respect. The material displaced by the outer edge of the pile in driving, enters and fills the sealing pocket below the point of penetration, and as the next pile is entered and driven, this material is further compressed, thereby further sealing the joint.

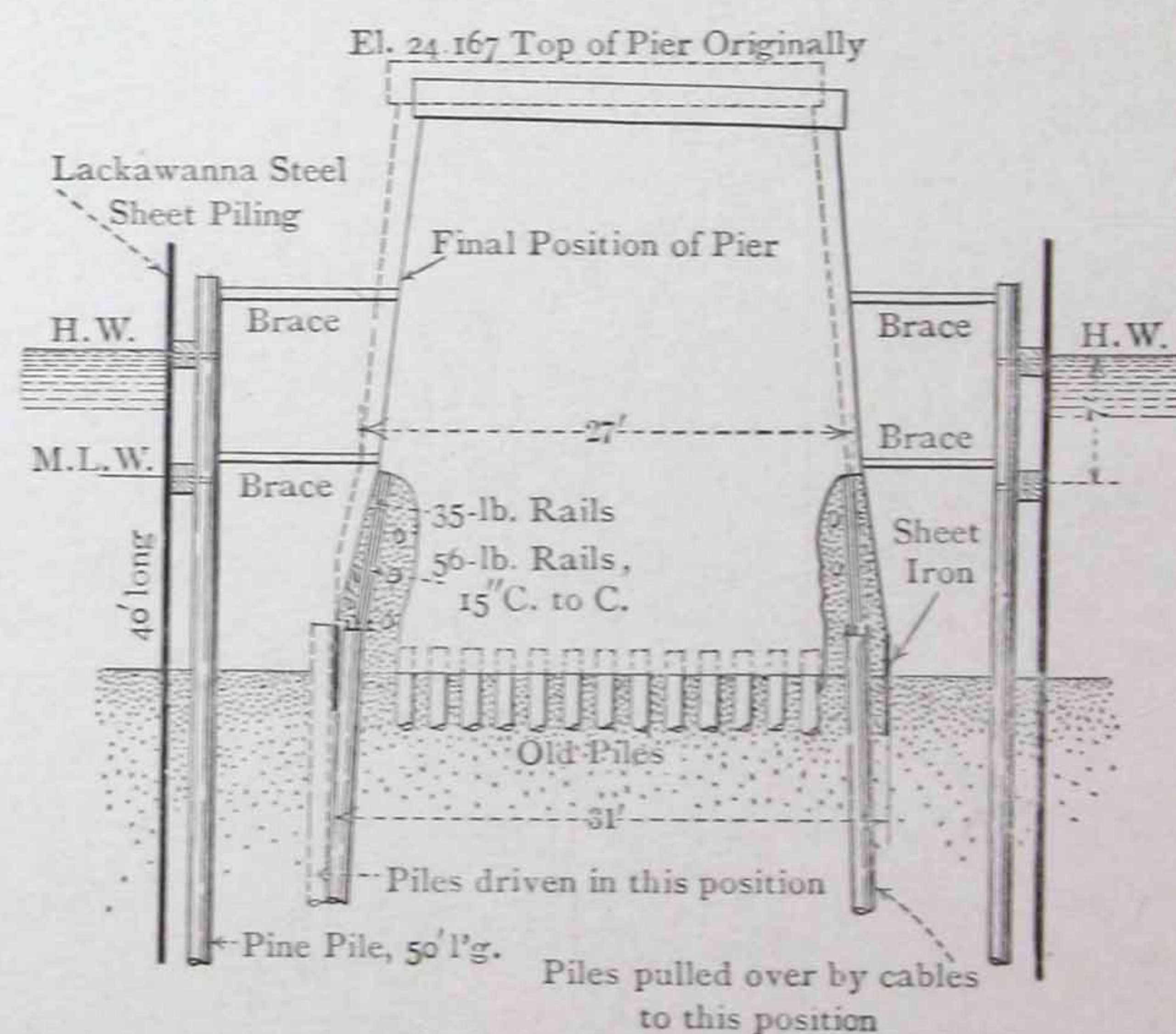
Experience has demonstrated that any minor leaks which develop are usually stopped auto-

matically by the silt or mud carried in suspension in the water and thence into the joint by the pressure. Such material deposits in the joint because the water must assume a tortuous path in attempting to pass the three points of contact.

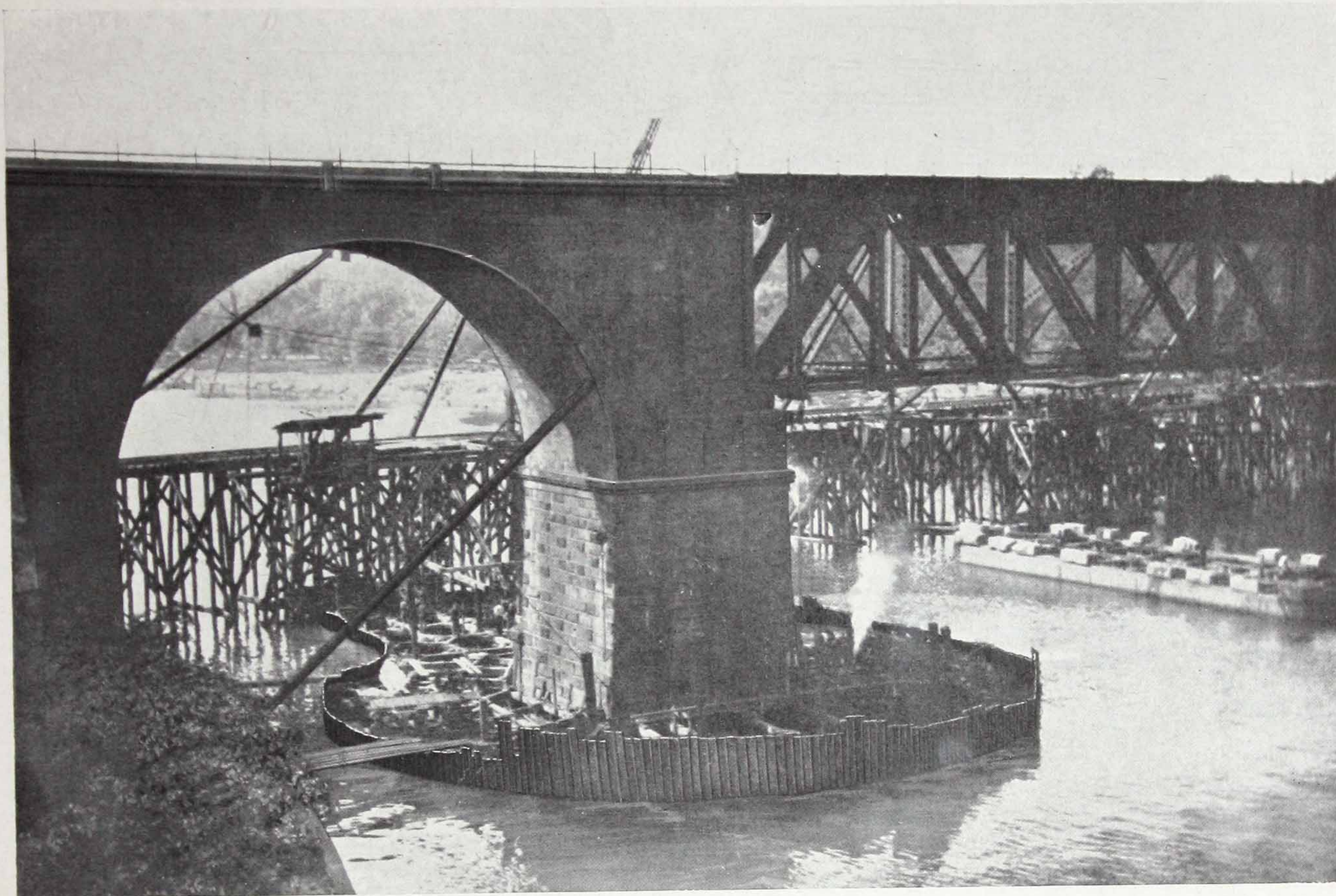
Further, as the pressure accumulates on the outside of the piling wall, due to the removal of the interior material, the clearance in the



Cofferdam of Lackawanna Steel Sheet Piling in 40-foot lengths, utilized in strengthening a circular bridge pier which had settled because of unstable soil around the bearing piles. Within the cofferdam, twenty-five 65-foot wooden piles were jettied and driven around and close to the pier at intervals of about 2 feet 6 inches to an average depth of 38 feet. The cofferdam was then pumped out, the reinforcing piles cut off about 3 feet above the river bed, the concrete cut away for about 3 feet to a height of about 3 feet above the top of the piles. The piles were then pulled over and held to new position under ledge by steel cables and surrounded with new concrete in which was embedded 35-lb. rails placed horizontally and vertically for reinforcement. Although at times clear water surrounded this cofferdam to a depth of 20 feet, no trouble was experienced in maintaining dryness within, the piling joints being caulked with sawdust and cinders.



Lackawanna Steel Sheet Piling



The old (built in 1866) two-track main-line Pennsylvania Railroad Bridge over the Schuylkill River is still in such good condition that the railroad decided to add three more tracks, widen the piers correspondingly and ultimately substitute two concrete arches for the central steel truss. The picture shows a Lackawanna Sheet Piling cofferdam driven around an old pier by the contractors, Eyre-Shoemaker, Ltd., to permit unwatering and placing new concrete. Cofferdam stands in 22 feet of water.

The Lackawanna Sheet Piling proved very satisfactory as regards driving, watertightness and strength, and was pulled and further used for two successive subsequent installations around other piers.

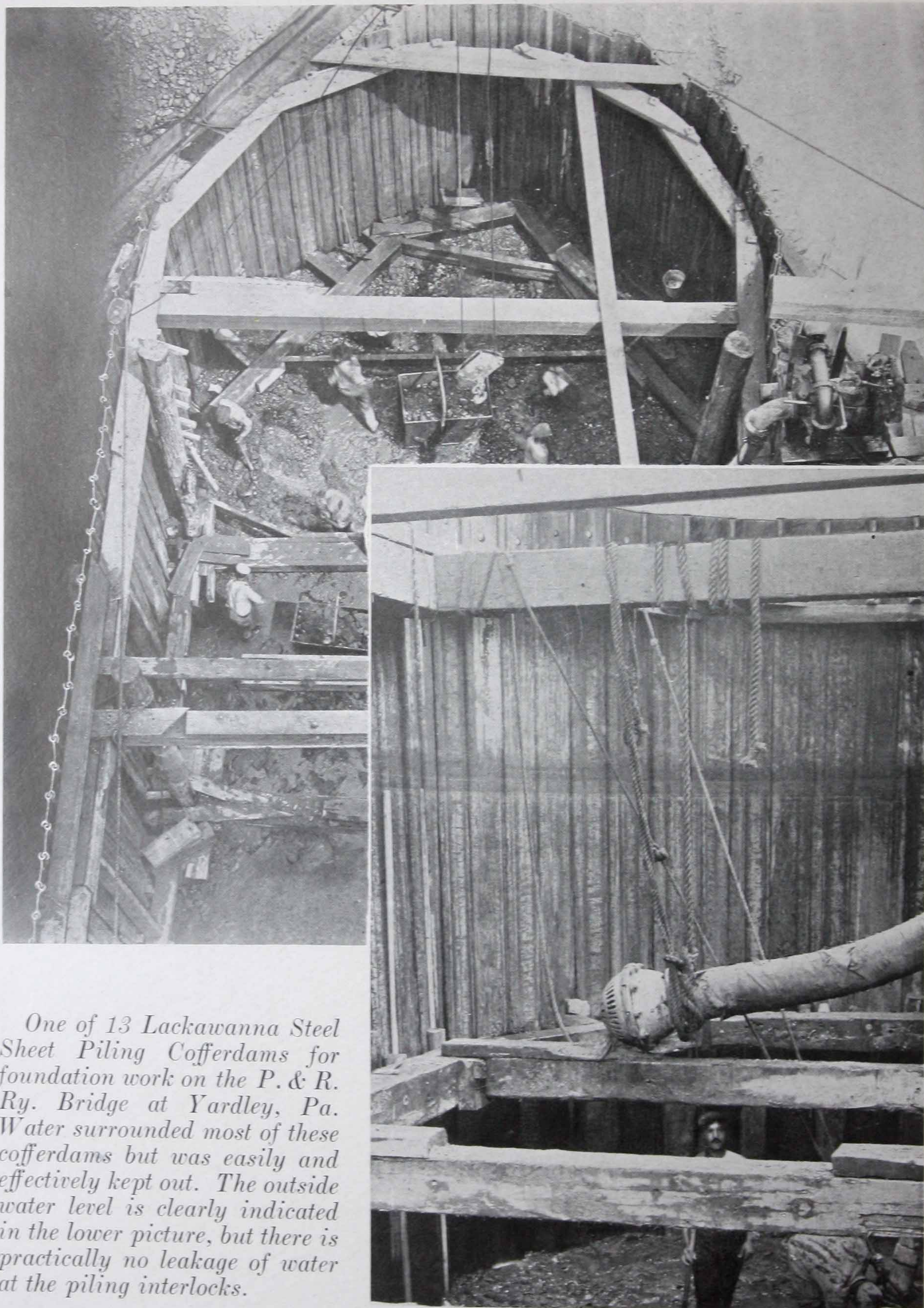
interlocked joints is reduced, and the joints closed more tightly, as the outside pressure increases.

This is particularly true in braced structures of Lackawanna Arched-Web Sheet Piling, where the web of every second piling section is in direct contact with the waling. (See diagram, page 17). Those sections with webs not in such contact are moved inward by external pressures to make a steel against steel line contact throughout. Large area water cofferdams so made, therefore, become thoroughly watertight without artificial packing of the joints.

Watertightness may also be increased, in case

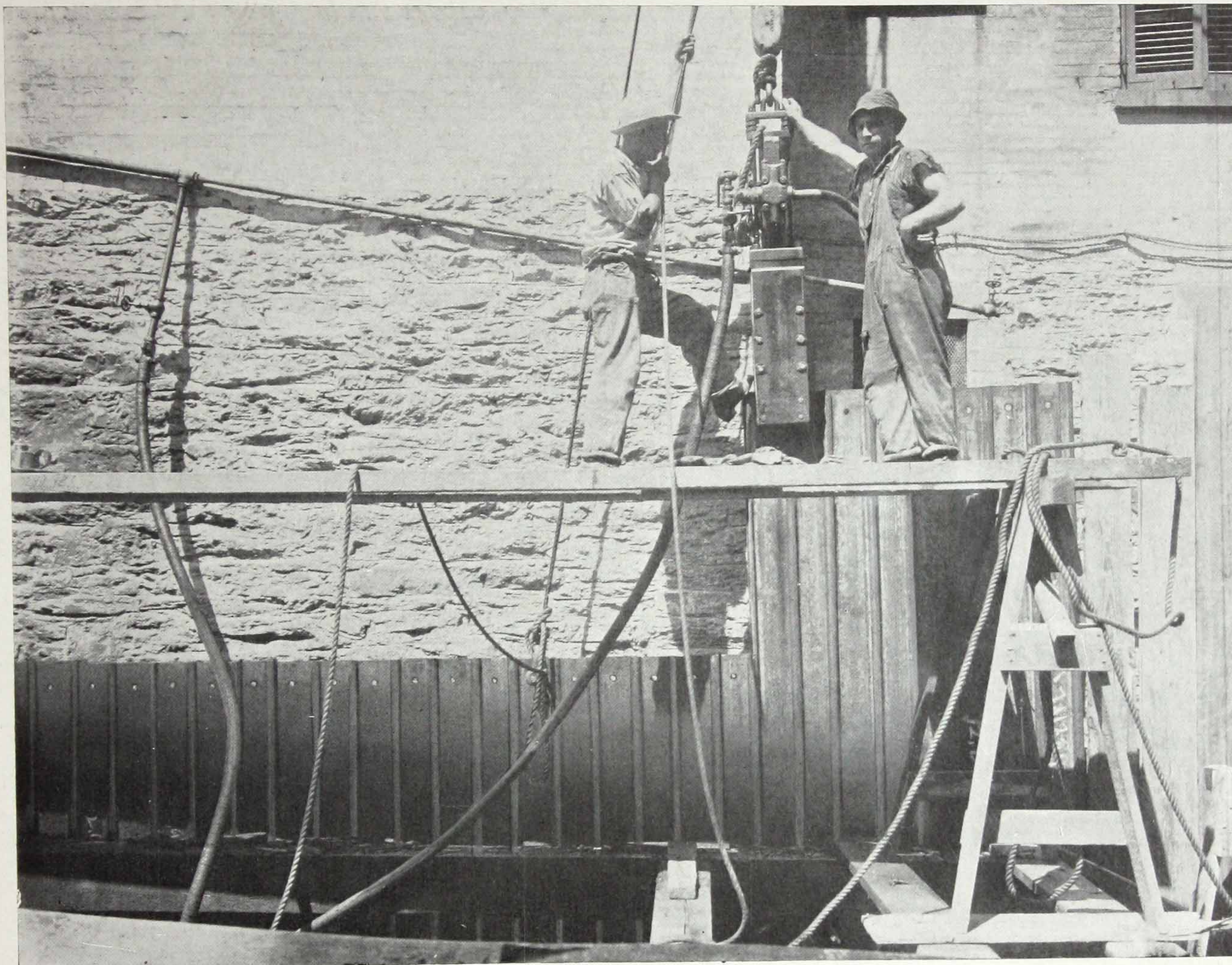
of emergency, by filling the sealing pockets of the interlocked joints, after driving, with cinders, wood pulp, coal dust, manure or other available local material. Two good examples of this procedure are the cofferdam shown on opposite page and the cofferdam in the Passaic River as shown on page 38.

Where the piling is to remain in place, that is, in permanent constructions, it is a great advantage to fill the sealing pockets of the joints above the point of penetration with cement grout. This absolutely seals the joints and causes the parts of the interlock to become integral and work as a single unit.



One of 13 Lackawanna Steel Sheet Piling Cofferdams for foundation work on the P. & R. Ry. Bridge at Yardley, Pa. Water surrounded most of these cofferdams but was easily and effectively kept out. The outside water level is clearly indicated in the lower picture, but there is practically no leakage of water at the piling interlocks.

Lackawanna Steel Sheet Piling



Driving a wall of 7-inch Lackawanna Steel Sheet Piling in 12-foot lengths. The close proximity of the piling wall to a foundation made no driving troubles; the two men easily handled the 640-lb. steam hammer, driving two piles at once through a soil containing sand and coarse gravel.

Driving apparatus and requirements

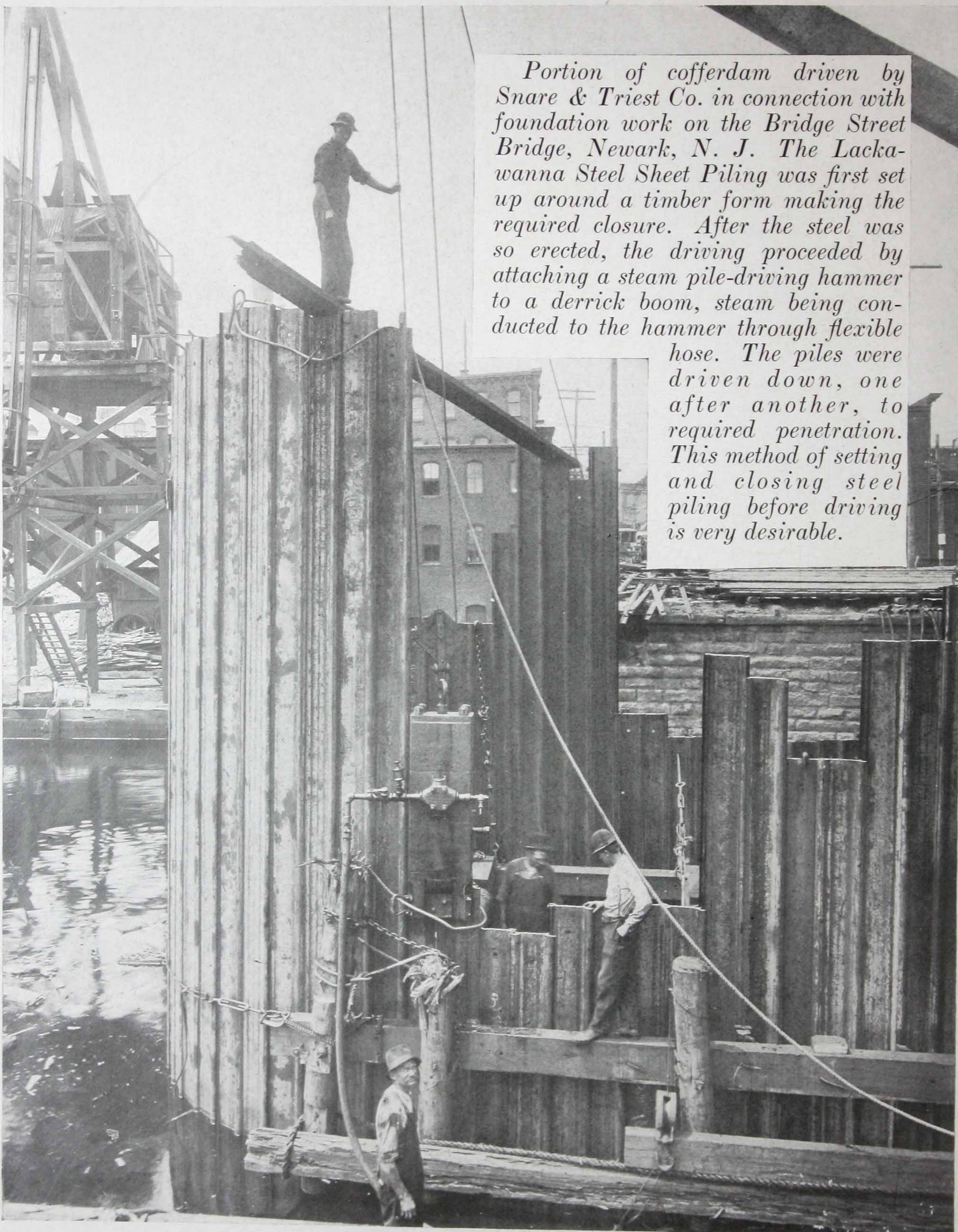
A DROP hammer, or steam or air hammer mounted upon a suitable rig, are the more common. The latter two are preferable because they put a constant weight upon the pile, deliver quick, short blows which keep the pile moving, are less apt to batter the piling tops, and as a rule do the most satisfactory work.

The choice of a driving hammer* is somewhat dependent upon the soil and the columnar strength of the pile, but, as a rule, a heavy hammer with

shorter and more rapid blows is preferable to a lighter hammer exerting the same number of foot pounds, but with heavier, less frequent blows.

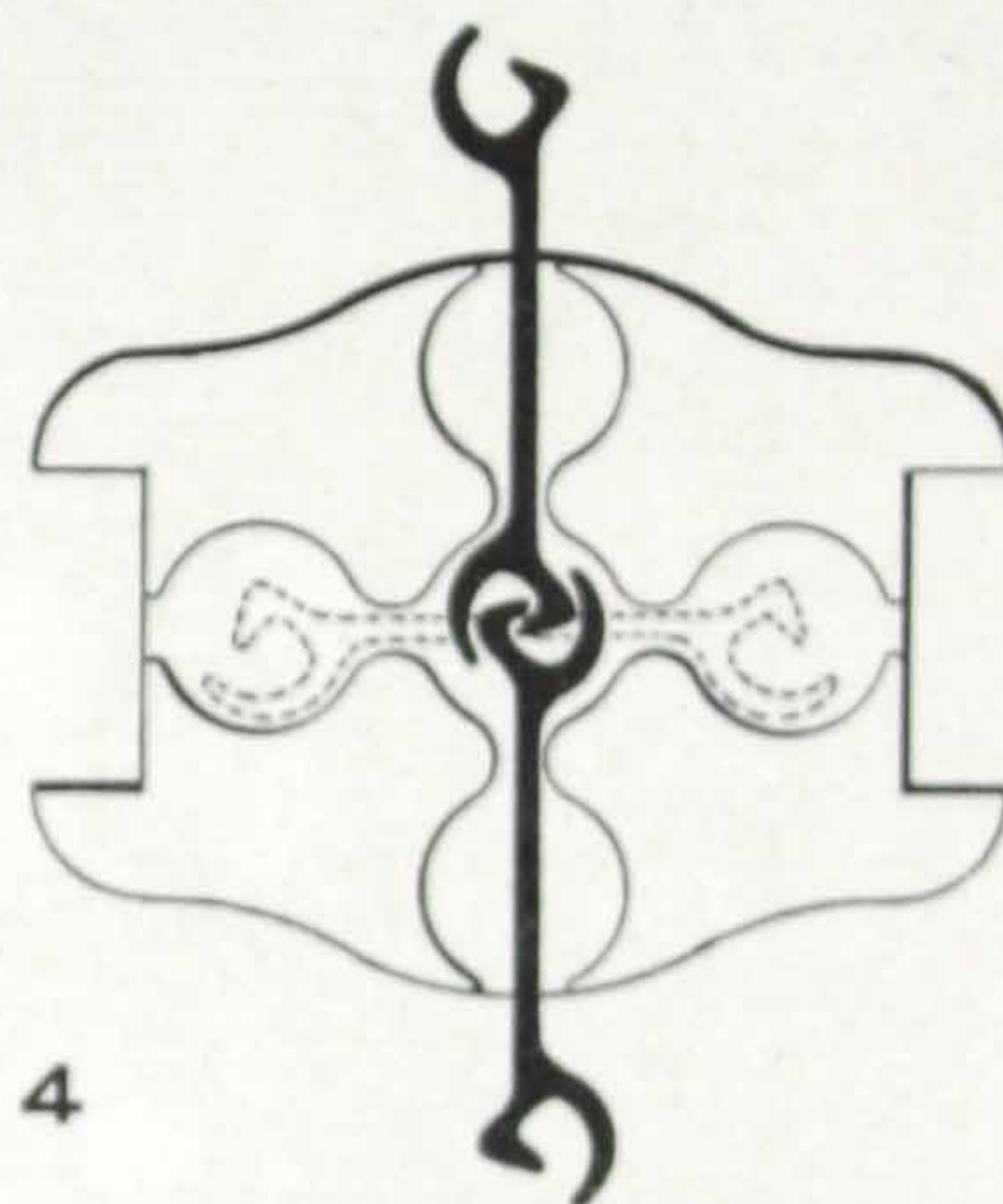
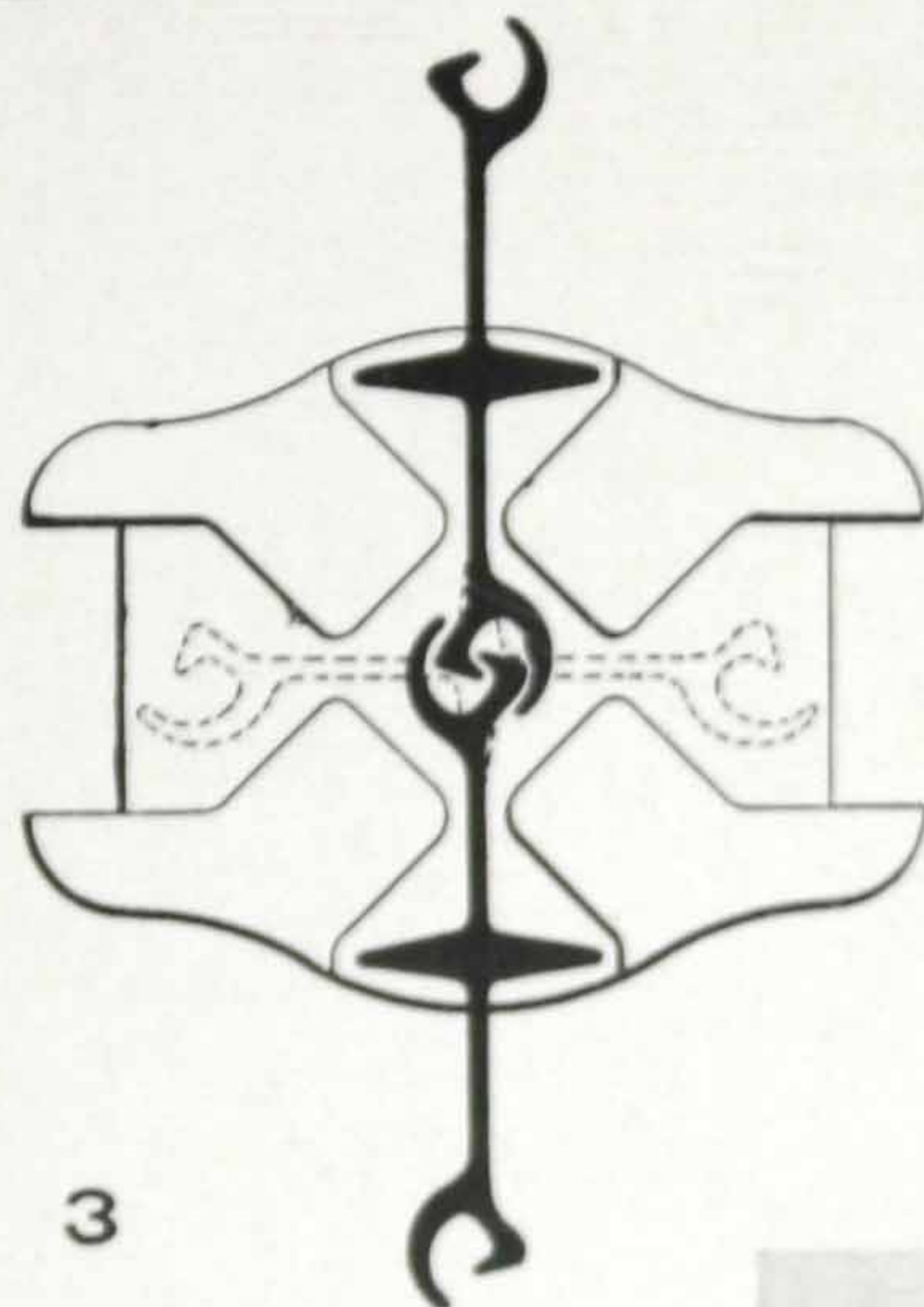
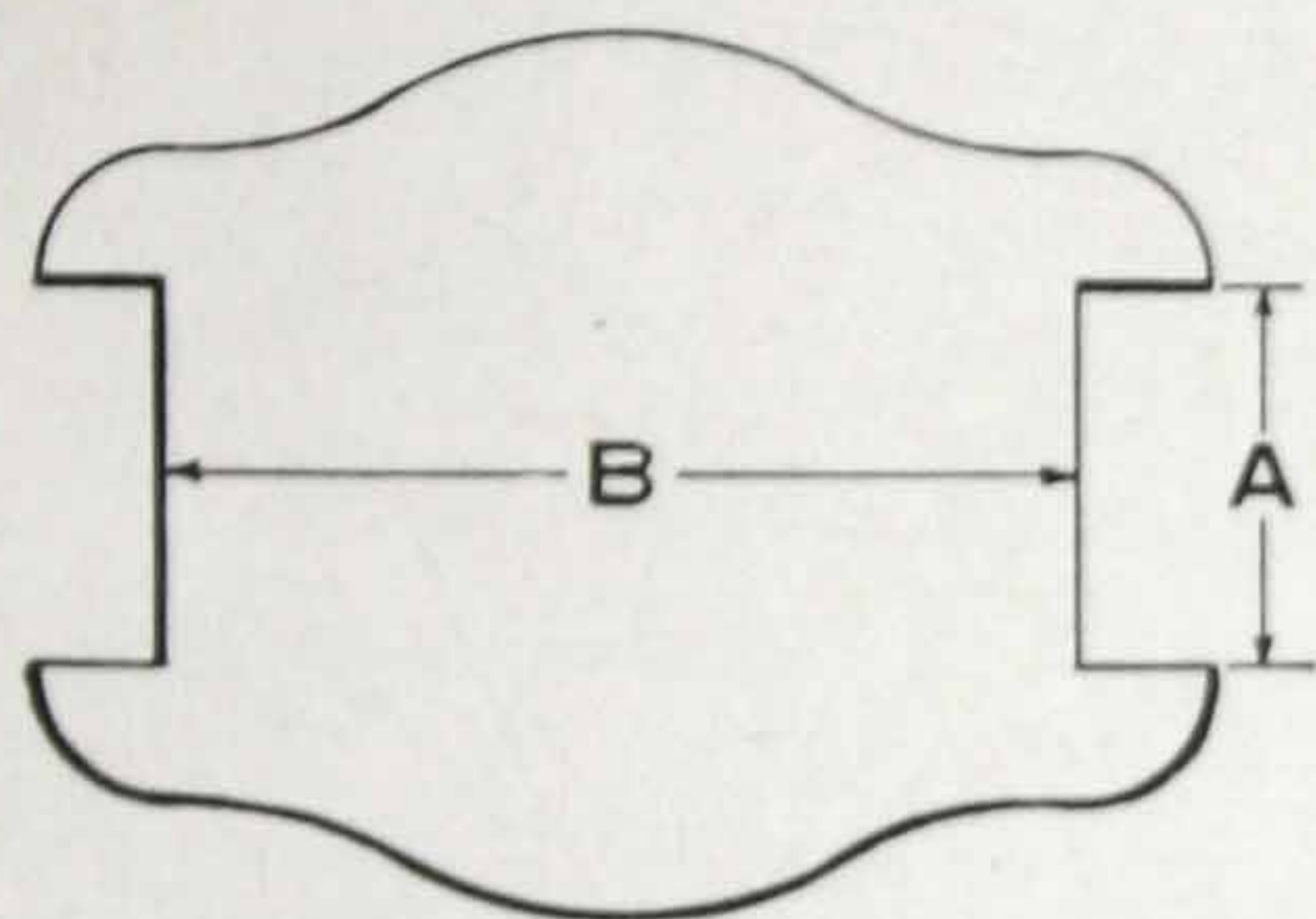
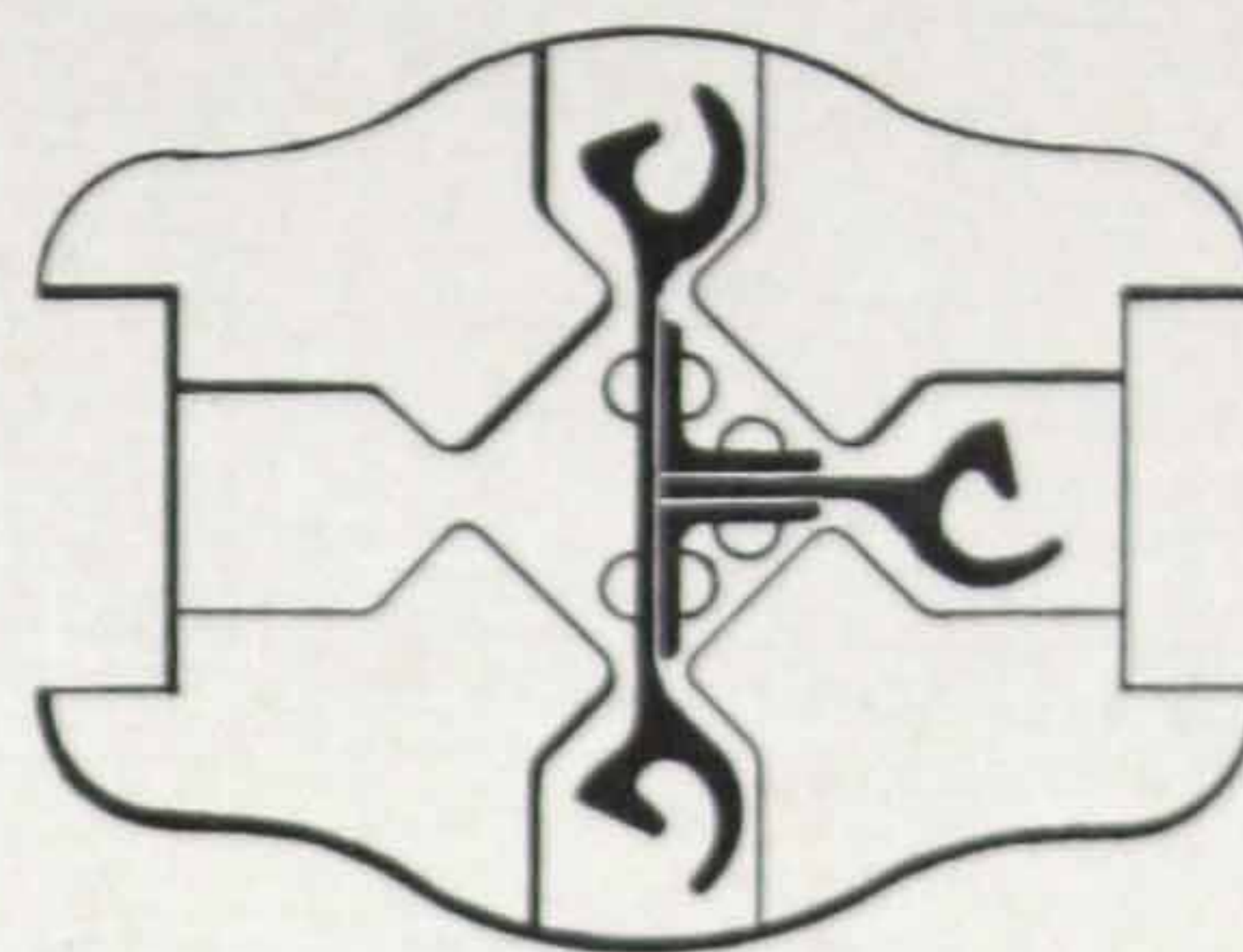
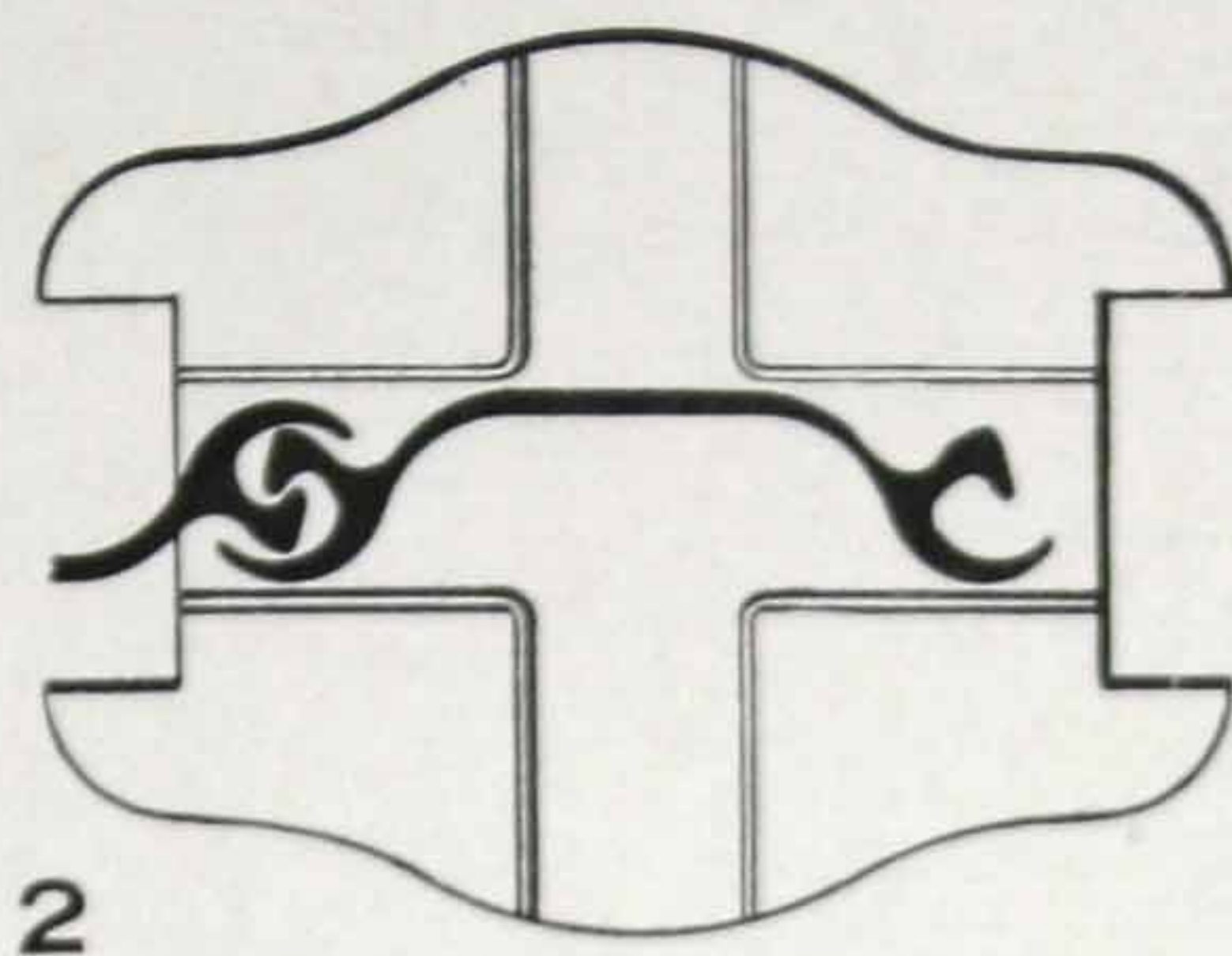
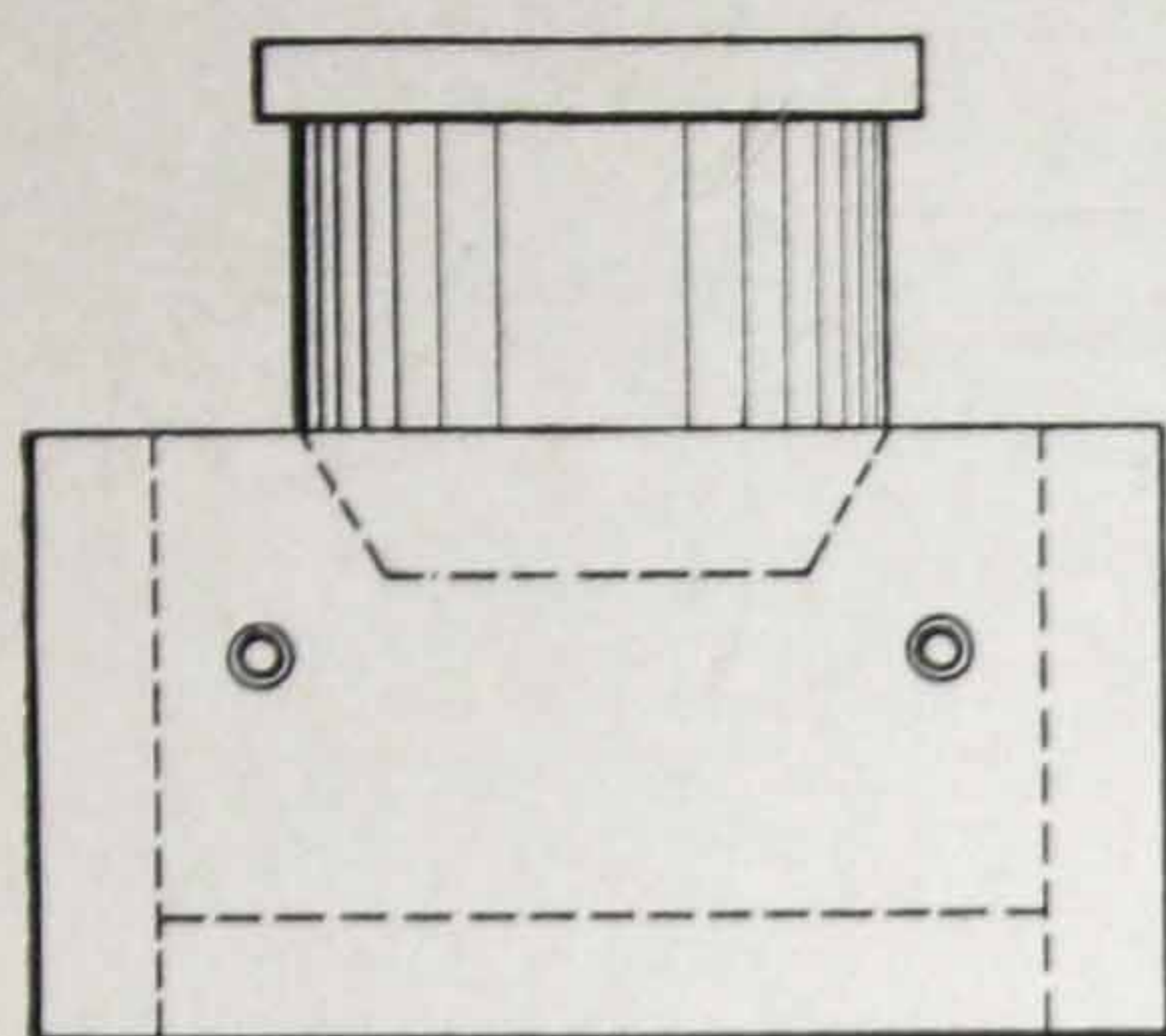
The use of a cap over the end of the pile while being driven is not always essential, but is recommended wherever hard driving is encoun-

** The following list includes most of the makers of hammers for driving steel sheet piling: McKiernan-Terry Drill Co., New York; Vulcan, Vulcan Iron Works, Chicago; Arnott, Union Iron Works, Hoboken, N. J.; Monarch, Henry J. McCoy Co., New York; Goubert, McKiernan-Terry, Ingersoll-Rand, Ingersoll-Rand Co., New York; Chicago Pneumatic, Chicago Pneumatic Tool Co., Chicago. In ordering from the makers, size of hammer, size of leaders (A in sketch, page 47) and distance between them (B in sketch) should be specified.*



Portion of cofferdam driven by Snare & Triest Co. in connection with foundation work on the Bridge Street Bridge, Newark, N. J. The Lackawanna Steel Sheet Piling was first set up around a timber form making the required closure. After the steel was so erected, the driving proceeded by attaching a steam pile-driving hammer to a derrick boom, steam being conducted to the hammer through flexible hose. The piles were driven down, one after another, to required penetration. This method of setting and closing steel piling before driving is very desirable.

Lackawanna Steel Sheet Piling

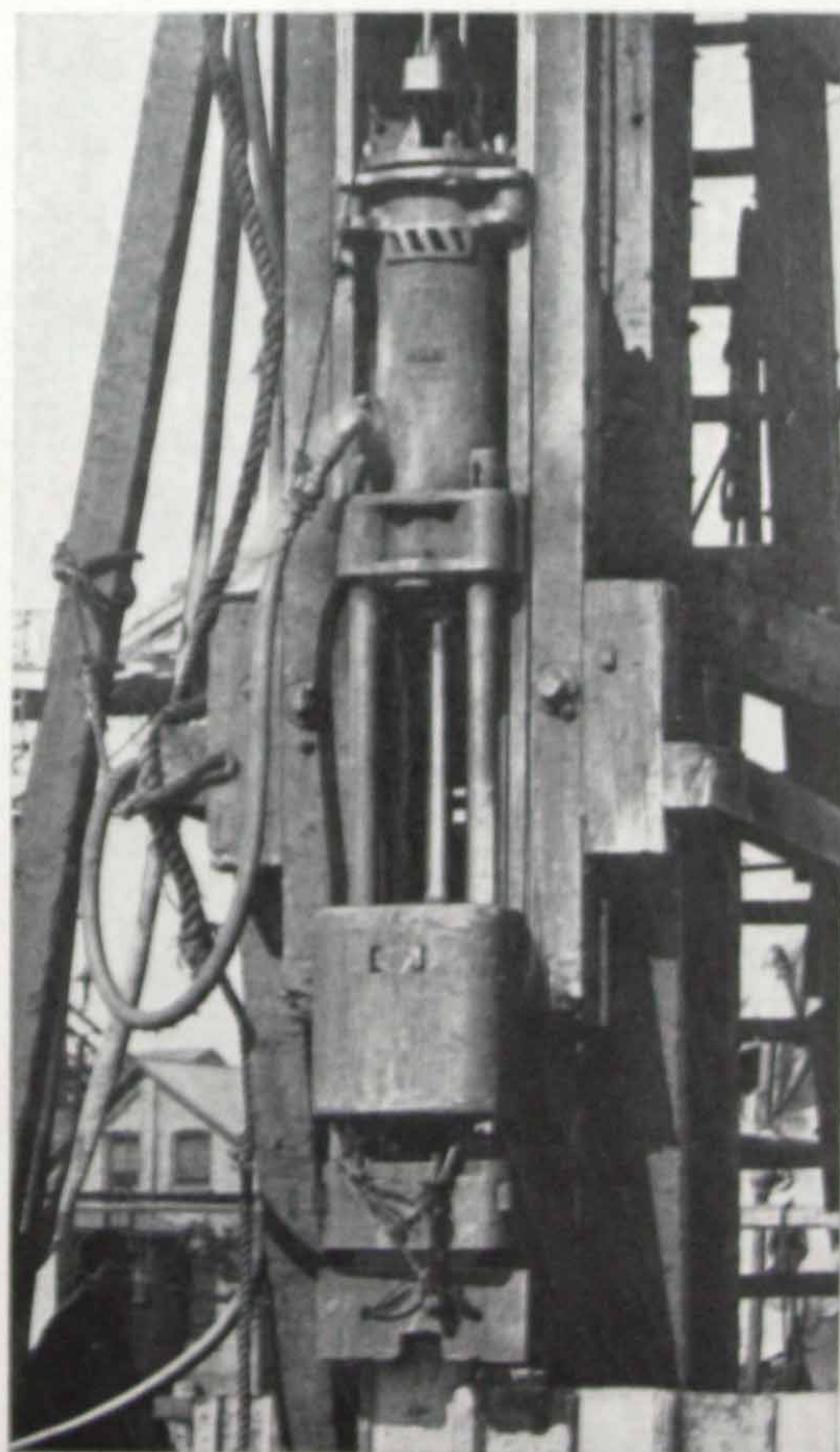


Types of caps suitable for use in driving Lackawanna Steel Sheet Piling. Nos. 1, 3 and 5 can be used for all types, but the latter two are preferable; No. 2 for Arched-Web; No. 3 for Center-Flange; No. 4 for Straight-Web; Nos. 3 and 5, preferably the latter, for fabricated corners, junctions and crosses. For details refer to catalogues of makers of hammers listed on page 45.

tered, to save the top of the pile from being battered. Piles which are to be pulled and reused should invariably be protected in this way, and as occasional piles must usually be withdrawn and redriven in any work, use of the driving cap is advisable.

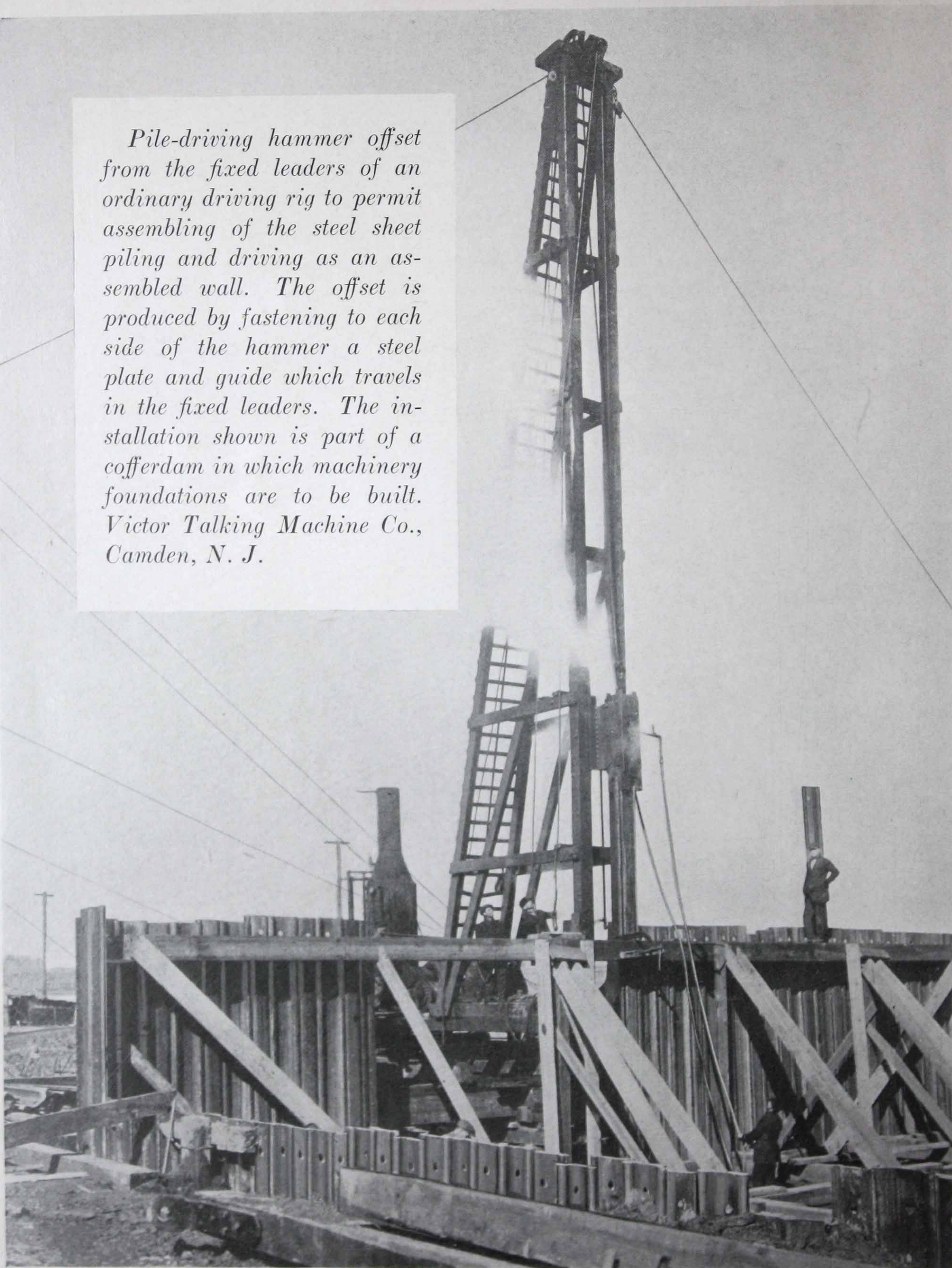
Good types of cap, each consisting of a steel casting, slotted to fit the pile-driver leads and the top of the pile and containing a recess in which a wooden block on end can be placed to cushion the blows of the hammer, are shown in detail and in use on this page. To provide the proper holding effect, the grooves should be made to conform as closely as practical to the shape of the pile, and as either groove may be used, the hammer can

Five-ton steam hammer, showing driving cap with wood cushion over cap.

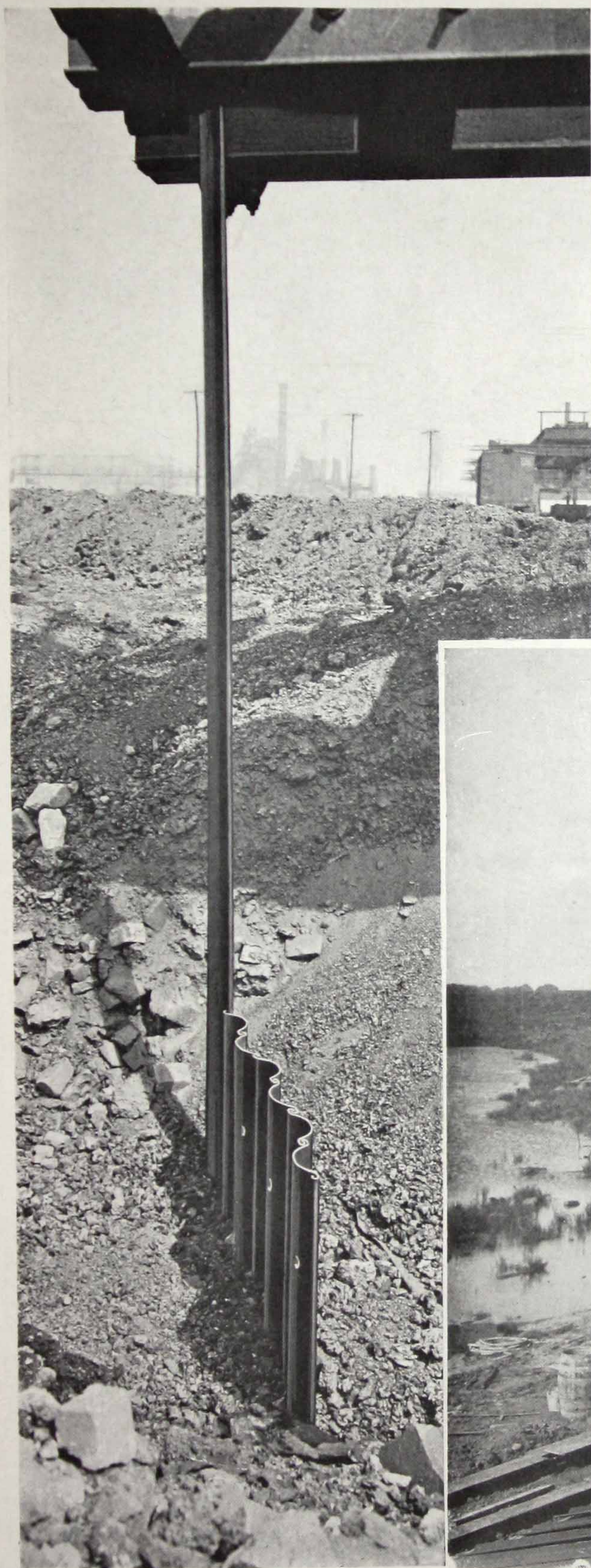




Pile-driving hammer offset from the fixed leaders of an ordinary driving rig to permit assembling of the steel sheet piling and driving as an assembled wall. The offset is produced by fastening to each side of the hammer a steel plate and guide which travels in the fixed leaders. The installation shown is part of a cofferdam in which machinery foundations are to be built. Victor Talking Machine Co., Camden, N. J.



Lackawanna Steel Sheet Piling



be made to straddle the piling line or operate at right angles to it.

A cap should properly be of the same width and have same clearances at leaders as the hammer with which it is used, and should be provided with holes which will permit it to be tied to the hammer, so that the cap may be made to lift away from the driven pile with the hammer body. We are always ready to advise as to proper cap design and the securing of suitable caps.

Driving piling under water or below the pile-driver leads is facilitated by using a follower, consisting of another pile fitted with projecting plates that conform with the section below.

Lackawanna Plate Sheet Piling being driven for cut-off wall in levee work on the Mississippi River, near New Orleans. (Lower picture.)



Lackawanna Plate Sheet Piling driven in 20-foot lengths under widely differing conditions.

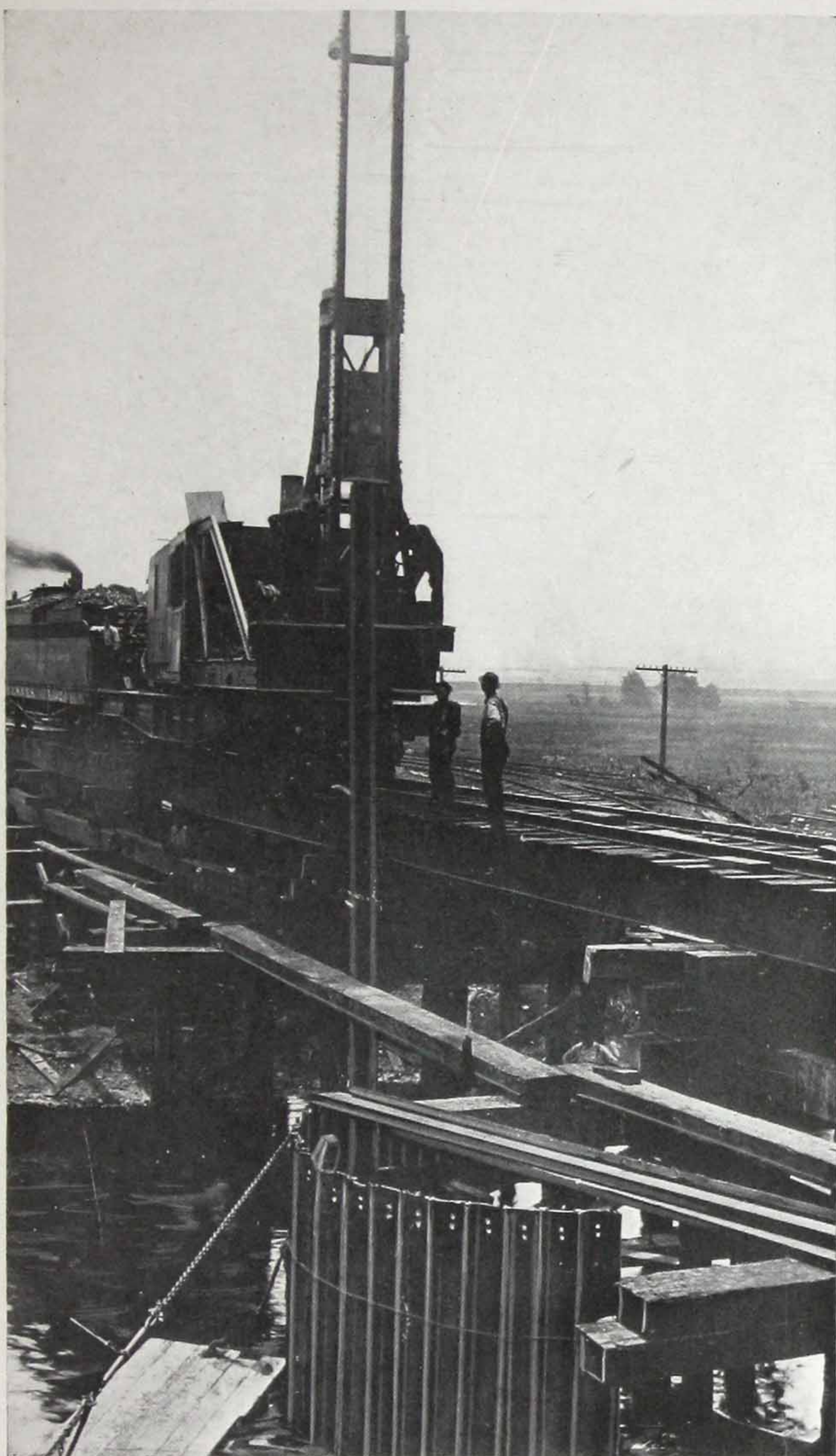


This wall of Lackawanna Steel Sheet Piling penetrated about 20 feet of riprap and boulders which had been placed to protect the pier. Where the obstructions became too great further driving was postponed until after partial excavation. Then a diver would go down with water jet, get a sling around the obstruction and lift it to the surface. One of the obstructions, a boulder of 8 feet largest dimension, is shown. Think of steel sheet piling being driven into such material!—and what is more remarkable, 95 per cent of this piling was found, upon pulling, to be satisfactory for re-use.

Part of a flinty limestone boulder severed by two sections of Lackawanna Arched-Web Piling which penetrated perfectly. Encountered in foundation work on the new L. S. & M. S. Ry. Bridge over Buffalo Creek. The half shown was taken from inside one of the circular caissons, the other half remaining outside.



Lackawanna Steel Sheet Piling



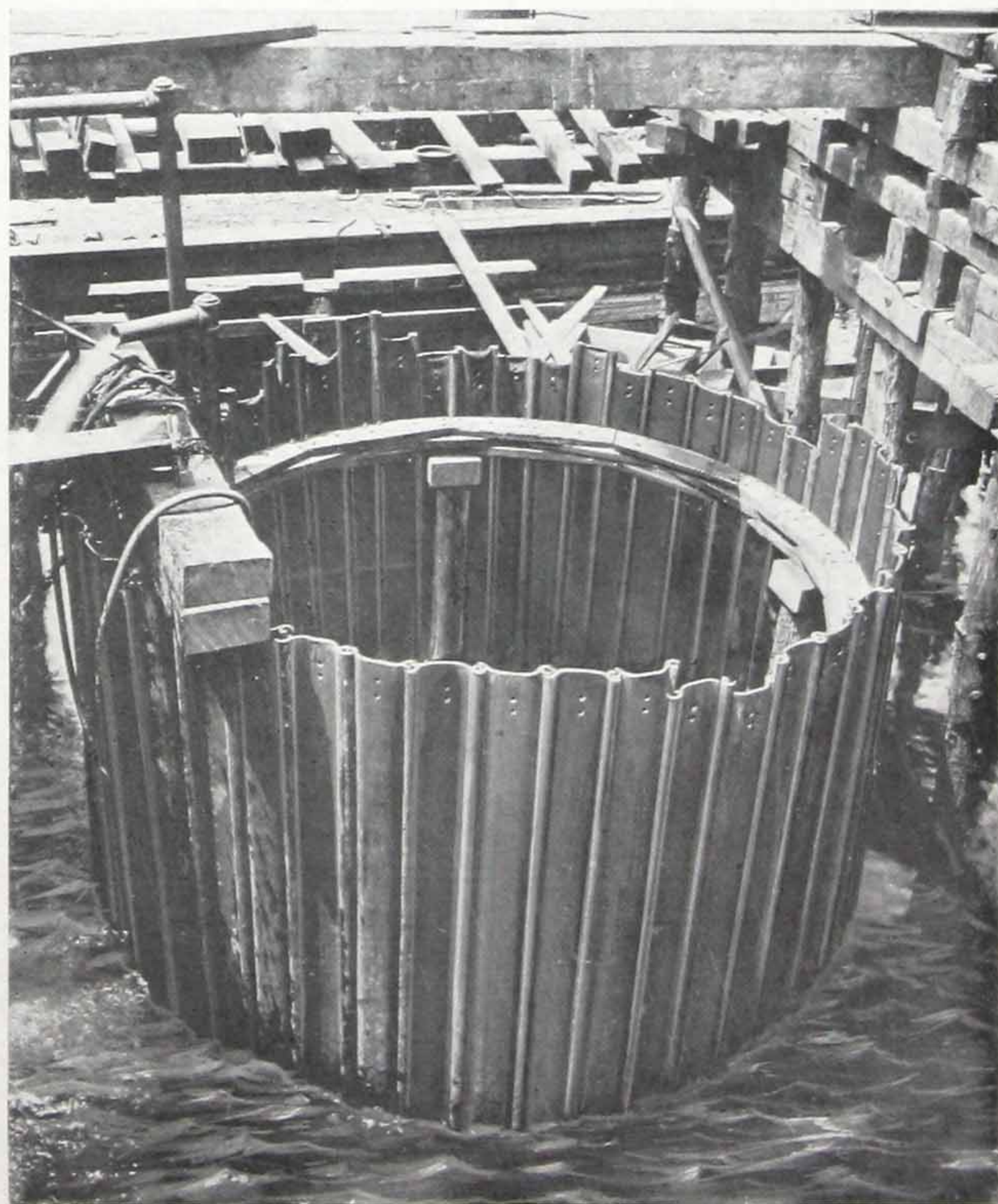
Driving Lackawanna Steel Sheet Piling caissons for pier foundations of the Lake Shore R. R. Bridge over Buffalo River.

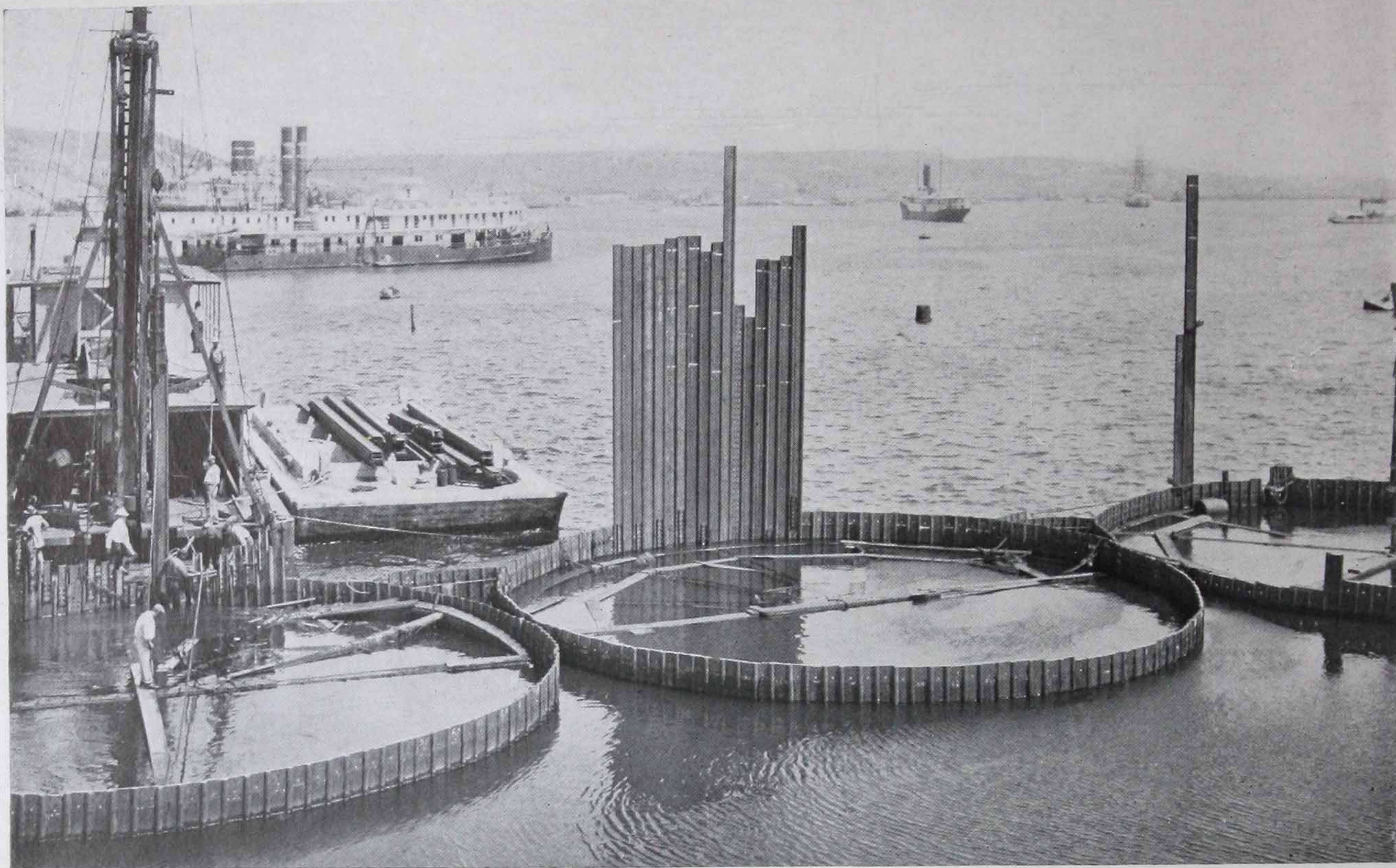
The eight caissons for the cylindrical piers of this bridge had to extend down to bedrock, about 36 feet below mean water level. Lackawanna Arched-Web Steel Sheet Piling was chosen for these caissons because of its extreme rigidity and easy driving and pulling qualities. Fifty piling sections in 45-foot lengths were driven for each caisson to form a cylinder 18 feet in diameter. The driving was accomplished, as shown in the upper picture, with a revolving pile driver mounted upon a car frame which ran upon temporary tracks.

To furnish a template or guide for driving

Lackawanna Steel Sheet Piling is strong and sharp enough to penetrate any soil formation except solid rock, and will go through submerged timbers without great difficulty. Two typical examples of boulders which were successfully gotten out of the way are shown on opposite page. We recall an instance where Lackawanna Piling severed a deeply buried railroad rail and another where a Lackawanna Piling wall which had been difficult to drive was found to have gone through a sunken canal boat loaded with stone.

the cylinders, five wooden piles were first driven, one in the center, and four at the corners of an inscribed square. Diagonal braces connected the circumferential piles, crossing at the center pile. A circular wooden frame or ring, 6 inches deep, and made up of three layers of 2-inch lumber was then attached to the top of the piles, as shown in the lower picture. Driving of the piling involved no difficulty, as the closures of every cylinder came together perfectly. After driving the steel piling, the two crossed timbers in each caisson were sawed off close to the driving form (as shown) to facilitate excavation.

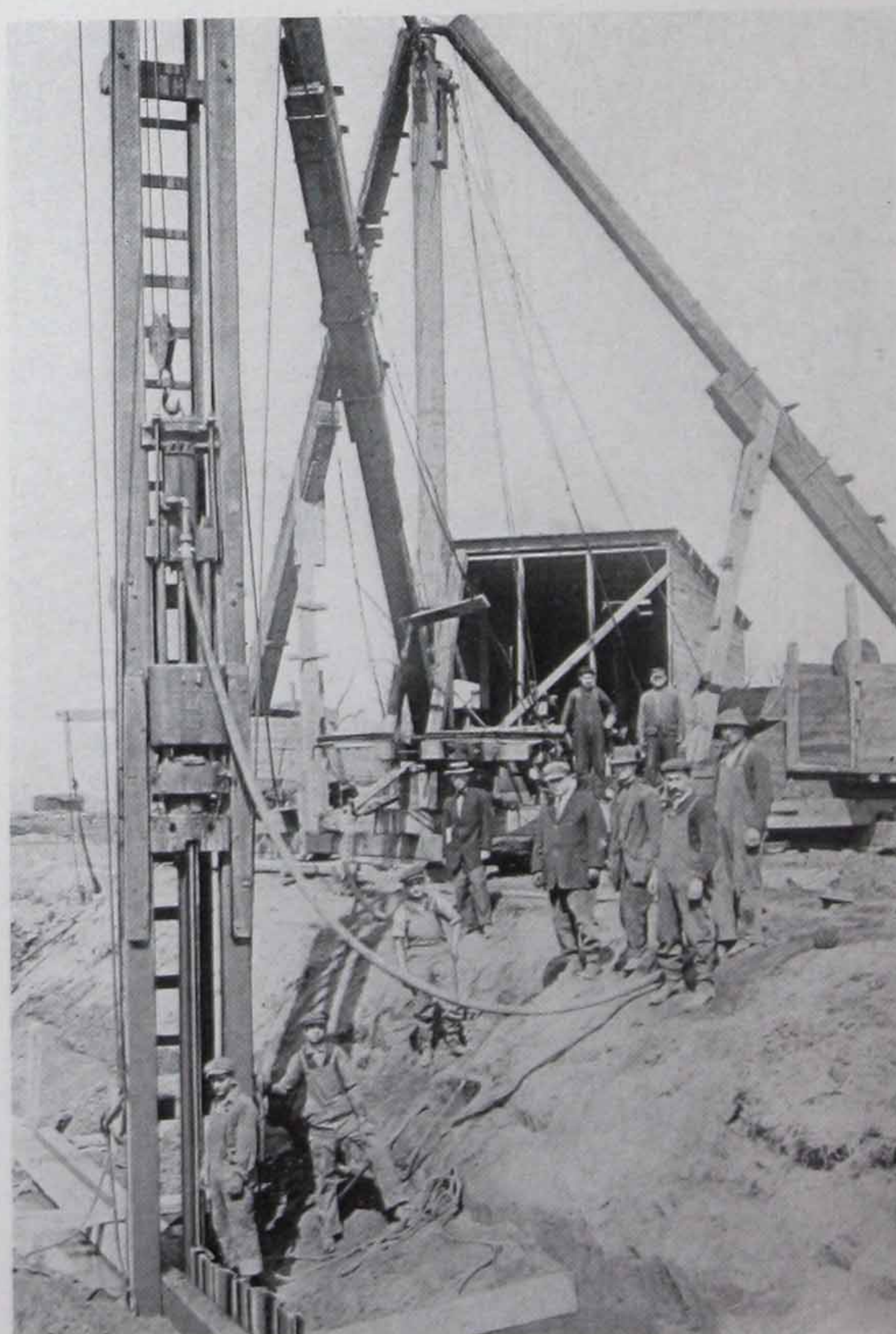




Effecting a closure in a 50-foot cylinder composed of 75-foot Lackawanna Steel Sheet Piling sections in spliced lengths. As will be noted, the final 17 piles were set at one time, driven to the water line and the top piling lengths spliced on. The higher top lengths were then driven to the level of the shorter top lengths and all 17 driven down a few feet at a time until the full penetration was reached. This is one of the twenty cylinders in the cofferdam for raising the battleship Maine.

The twenty cylinders and their connecting arcs in this cofferdam required 40 closures. That no fabricated closing sections were required on this entire job, is good evidence that closures with Lackawanna Steel Sheet Piling give no troubles.

False leaders used in connection with a steam derrick for driving Lackawanna Steel Sheet Piling in a dock wall.



Lackawanna Steel Sheet Piling

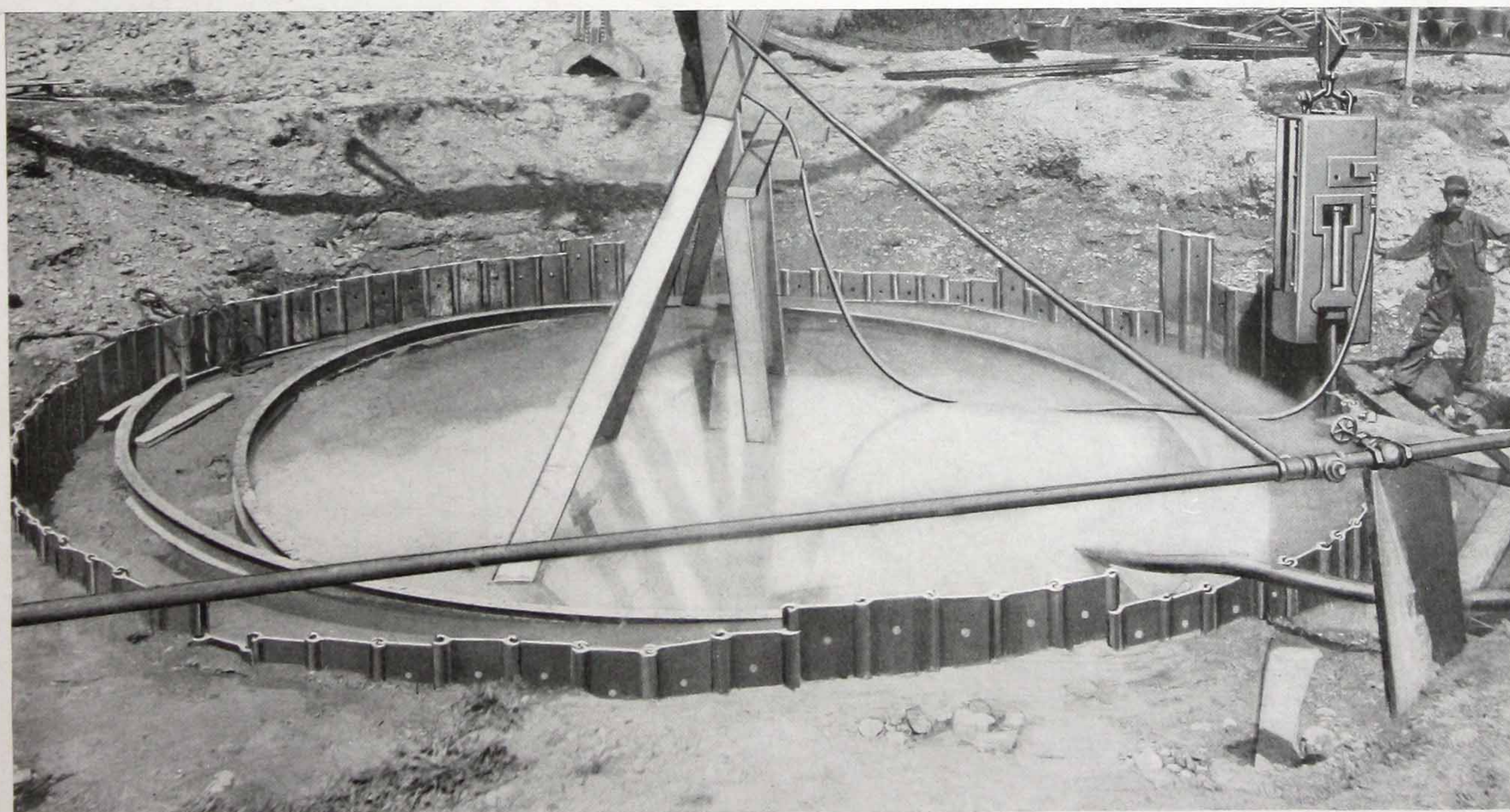
Care should be observed in driving to keep each pile plumb, and if the first pile driven is perfectly vertical, maintaining a wall straight or in true form, making closures will not prove difficult. Slight deviation of succeeding piles from correct position can easily be corrected by the use of a metal shim or wedge in the joint, or by holding the piling tops with ropes toward the desired position. The clearance in the interlocked joint of Lackawanna Piling admits of latitude in making such corrections without hindrance to driving, or distortion of the piling.

Steel sheet piling that deflects badly or refuses to penetrate on account of serious buried obstructions should never be forced, otherwise it may separate at the interlock and be twisted out of usable shape. Failure under such conditions is not chargeable to the piling, but to inexperience on the part of user. Where the decreased movement of the piling under the hammer blows indicates serious obstruction, it is often advisable to continue the line, leaving the obstinate pile or piles projecting above the rest until after excava-

tion, when the obstruction may be removed and all parts of the piling wall properly set.

Few deep walls of steel sheet piling are driven without meeting some obstruction in the form of large or small boulders, old logs, etc., but as an alternative of leaving a wall partially driven, the flexible joint of Lackawanna Steel Sheet Piling invariably offers the solution in emergencies, by permitting the wall to be deflected locally around an impenetrable obstruction. (See page 12.)

Effecting the closure in a cofferdam or joining the parts of a continuous piling wall where the driving has been started from several points simultaneously is a very simple matter with Lackawanna Steel Sheet Piling that has been driven plumb. As the ends of the piling wall approach each other the last few sections to make the closure should be set up and driven successively, each pile a short distance at a time, so as to assure proper spacing and alignment. Should the line of piling deflect from vertical or go too far forward at top or bottom, closure can be effected by using a special fabricated pile of suitable



Circular construction of Lackawanna Straight-Web Steel Sheet Piling. The piling sections were first set up around a driving form and a final closure made, after which they were driven down to final position, as shown, by a swinging hammer. Note the even curvature throughout the circle.



wedge dimensions to compensate for the irregularity. If such wedge is necessary it should be placed *before* reaching the closure point, thus straightening the line before reaching the juncture. A wedge is seldom necessary, and never, when all the sheet piling, including the closure, can be assembled complete before driving. Hence it is better to do this whenever possible and thus surely avoid any doubt.

The cost of driving Lackawanna Steel Sheet Piling must necessarily depend so much upon the size, length and type of section used, the nature of the soil, the amount of piling used, local labor conditions, the method of driving, etc., that general figures are not practical. However, our engineers can usually cite driving costs for

some similar completed installation.

Cutting Steel Sheet Piling which has been driven

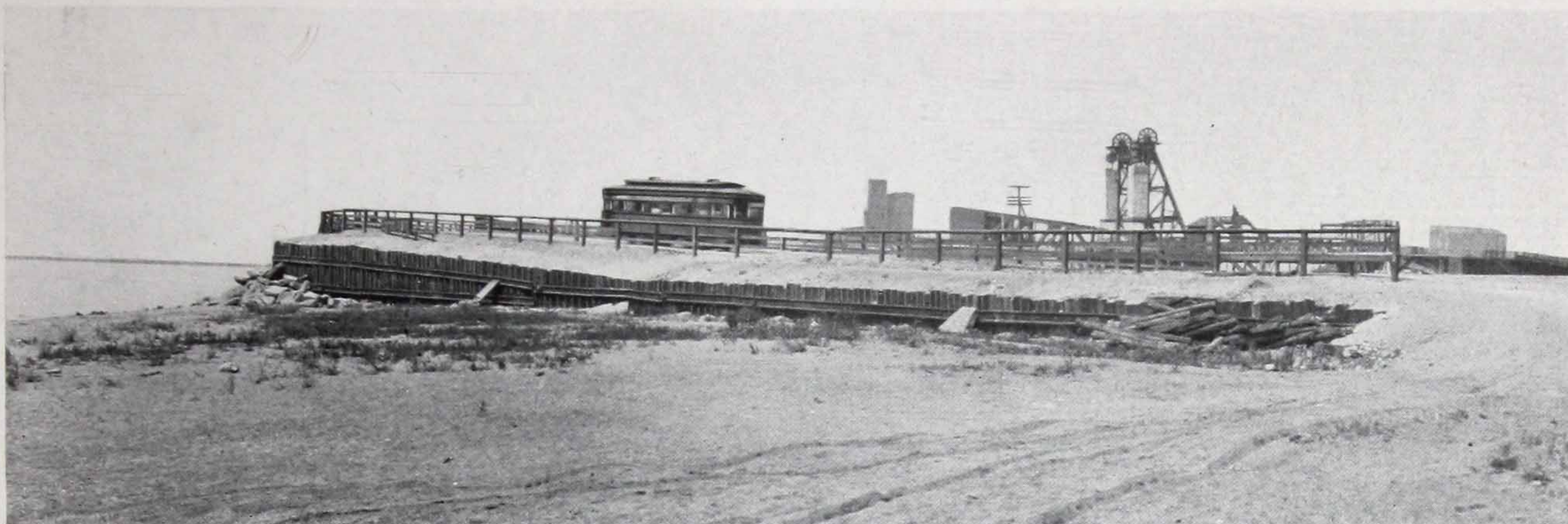
DRIVING Lackawanna Steel Sheet Piling to a nice uniform level seldom is difficult, but sometimes one or more piles strike bad obstructions before reaching the final depth, or for other reason the line of piling tops is irregular. Where such installations are permanent and for ornamental reasons or construction purposes, a straight line top is desirable on the piling wall, the piling may be cut to such line without particular difficulty.

Hacksaws may be used at reasonable cost for



Method of cutting Lackawanna Steel Sheet Piling by the oxy-acetylene process. In the above instance the piling had been driven for temporary service and extended irregularly above the water level, but later it was deemed useful as a permanent installation. Appearances and a free flow of water demanded that the piling be cut to water level of the lake and to conform with the riprap on the shore. Altogether about 200 feet of wall were cut in average working time of seven minutes per 12 $\frac{3}{4}$ -inch piling section.

Lackawanna Steel Sheet Piling



Lackawanna Steel Sheet Piling that had been pulled and redriven in cofferdam work six to eight times. Some of this steel sheet piling had penetrated through broken stone in previous installations. Finally installed as a permanent retaining wall.

work where time is not important, but the electric arc or oxy-acetylene torch is more practical.

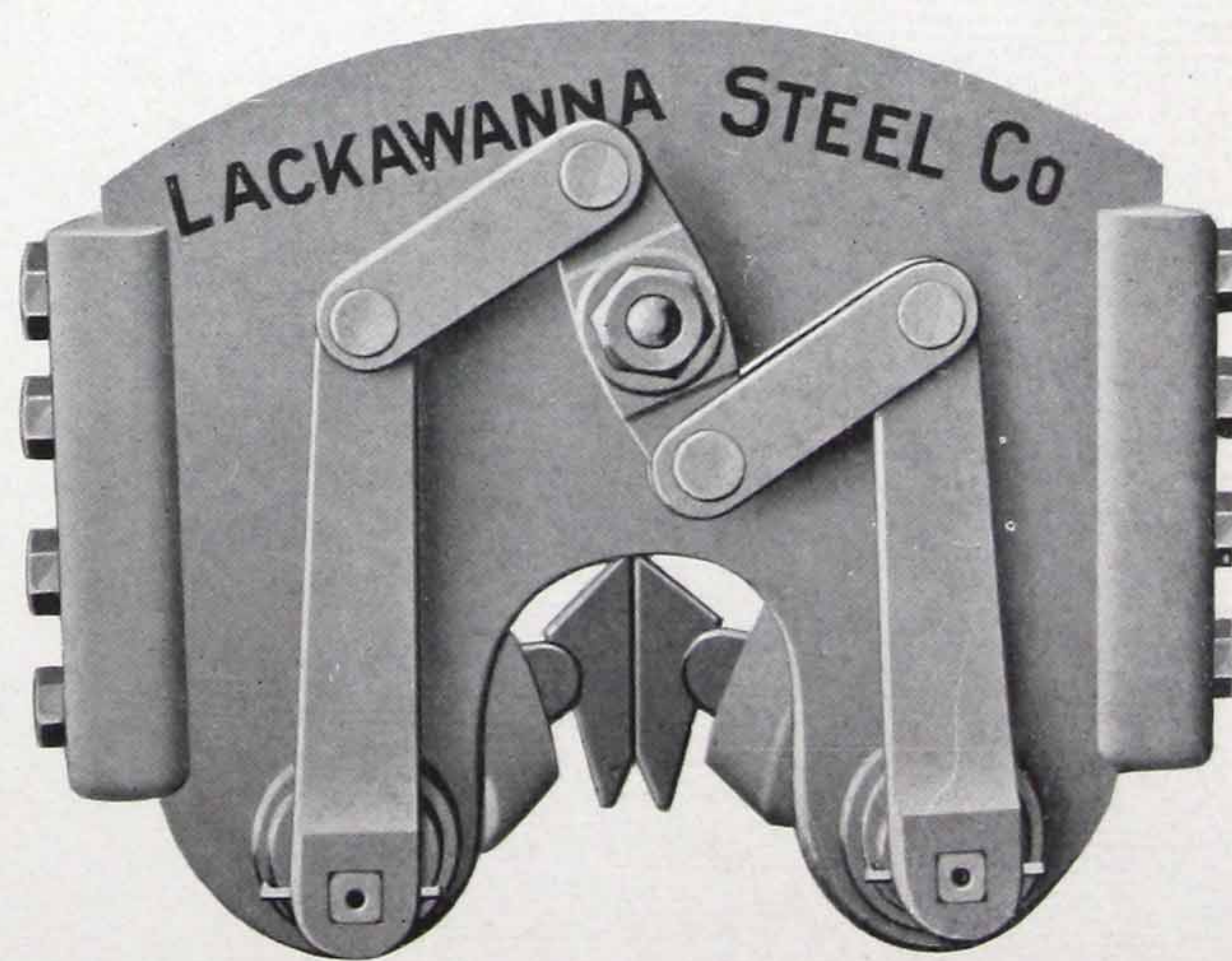
Pulling and redriving

OBVIOUSLY a type of piling that drives easily, pulls easily and should be good for practically 100 per cent salvage, so in the majority of instances it is quite practical to pull and redrive Lackawanna Steel Sheet Piling many times. In fact, for certain classes of work, some contractors look upon Lackawanna Piling as equipment to be used over and over before ultimately sold as scrap. An instance of many successive installations is cited in the illustration above. Other photos referring to reinstallation are included in this book as follows: at the Kinney Building, page 10; at the Tunkhannock Viaduct, page 27; at the 92nd Street Bridge, Chicago, page 30; on Pennsylvania Railroad bridge foundation, page 43; in the Passaic River, page 38; after driving through riprap, page 50.

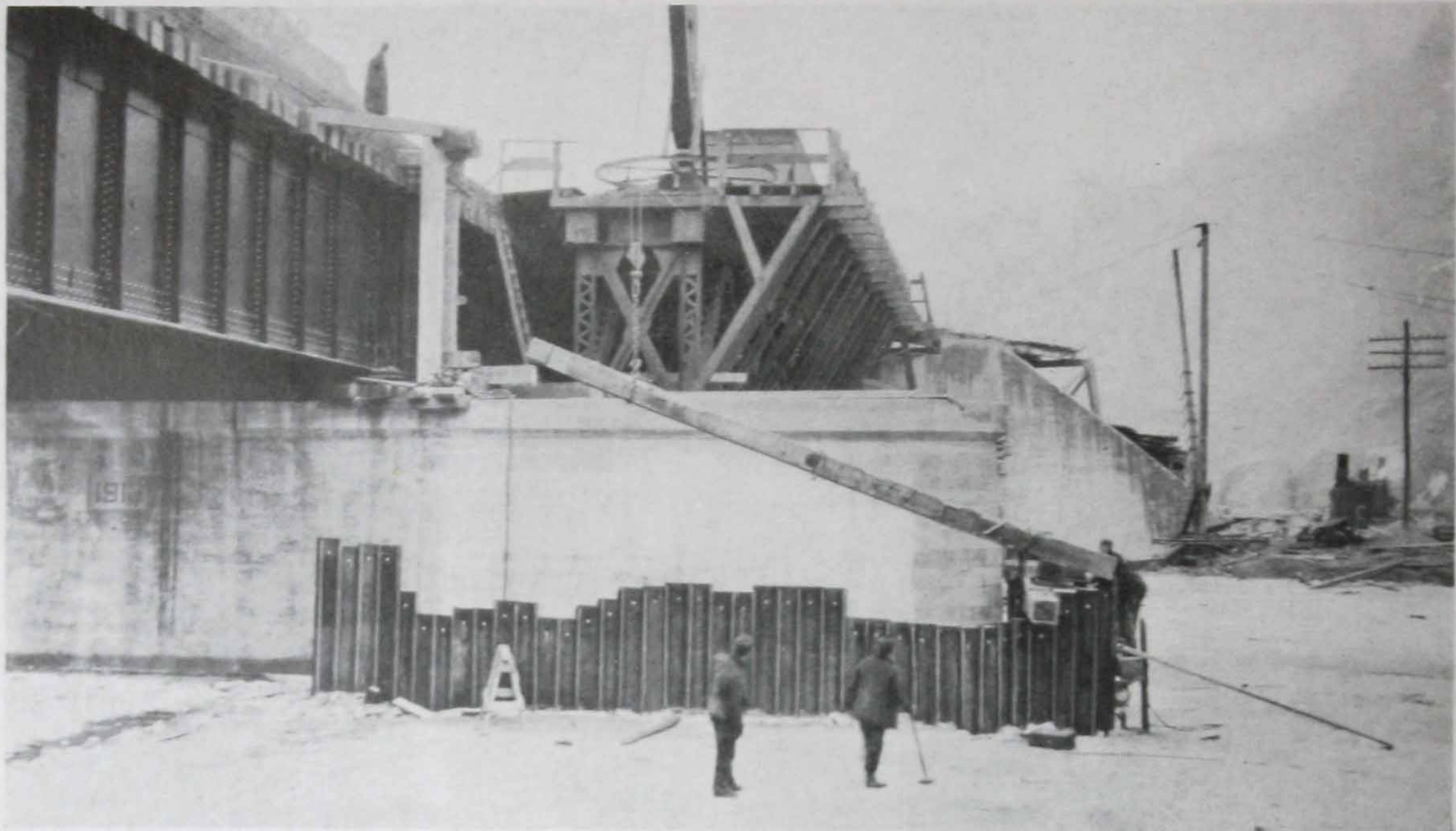
Piling to be pulled and reused should be carefully driven and the tops protected by a driving cap as previously explained. Short piling lengths may be pulled by a lever, by a tripod or by the cableways used to handle other construction material, the handling hole in the top of each pile providing a hold for a pulling attachment. A line of piling that is plumb and accurate may usually be pulled by the rig that does the driving.

A very satisfactory grip for pile pulling consists in part of two jaws which come over the

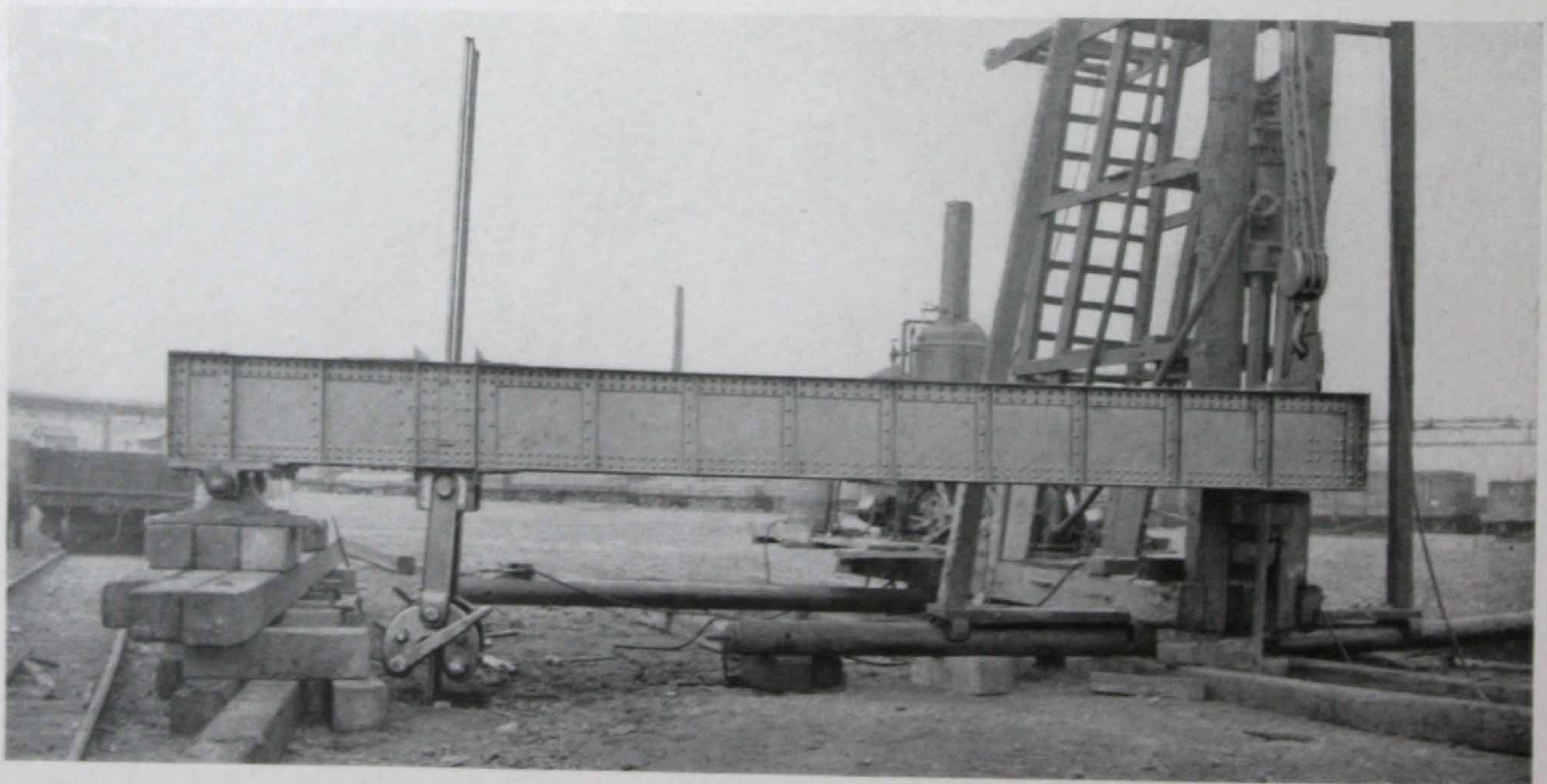
pile web. These jaws are held in contact with the web of pile by two toggle joints, which increase the holding power of said jaws as the heavier pulls are exerted by machine used. Piling that has been installed for a long time, and which on account of static pressure and possible accumulations of rust is difficult to pull, can usually be started by light downward taps from a pile hammer. Once the first pile is started the others come easier. It is good policy to grease or paint with graphite all interlocks of piles to be withdrawn, especially where the piles are to remain in position for a long time. Such a coating



Grip used for pulling the 75-foot spliced lengths of Lackawanna Steel Sheet Piling from the cofferdam around the U. S. S. Maine, Havana Harbor.



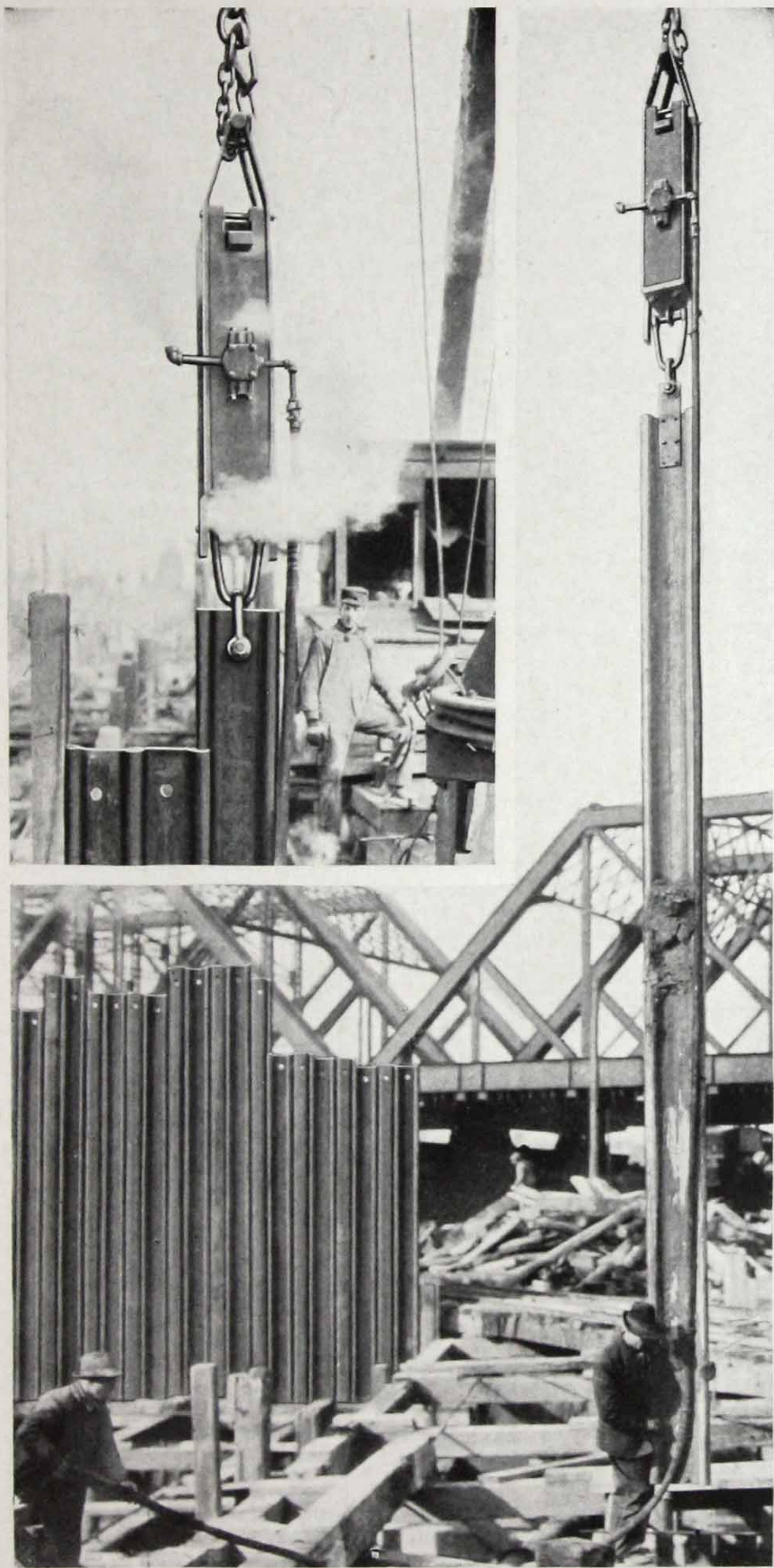
Pulling 25-foot lengths of Lackawanna Steel Sheet Piling by means of a timber lever and derrick. A machine bolt was put through the pulling hole in the pile and through iron straps on each side and the straps were connected by a chain to a 12-by-12 timber lever fulcrumed for 10 to 1 power increase. The fulcrum was blocked up to a desirable height and a pull of 4 to 6 tons was applied to the lower end, while a man with a sledge hammer tapped the pile to help loosen it.



Lever and grip successfully used in pulling Lackawanna Steel Sheet Piling that had penetrated 50 feet of cinders, soil and gravel.

Lackawanna Steel Sheet Piling

prevents rust and helps the joint contacts to slide past each other.



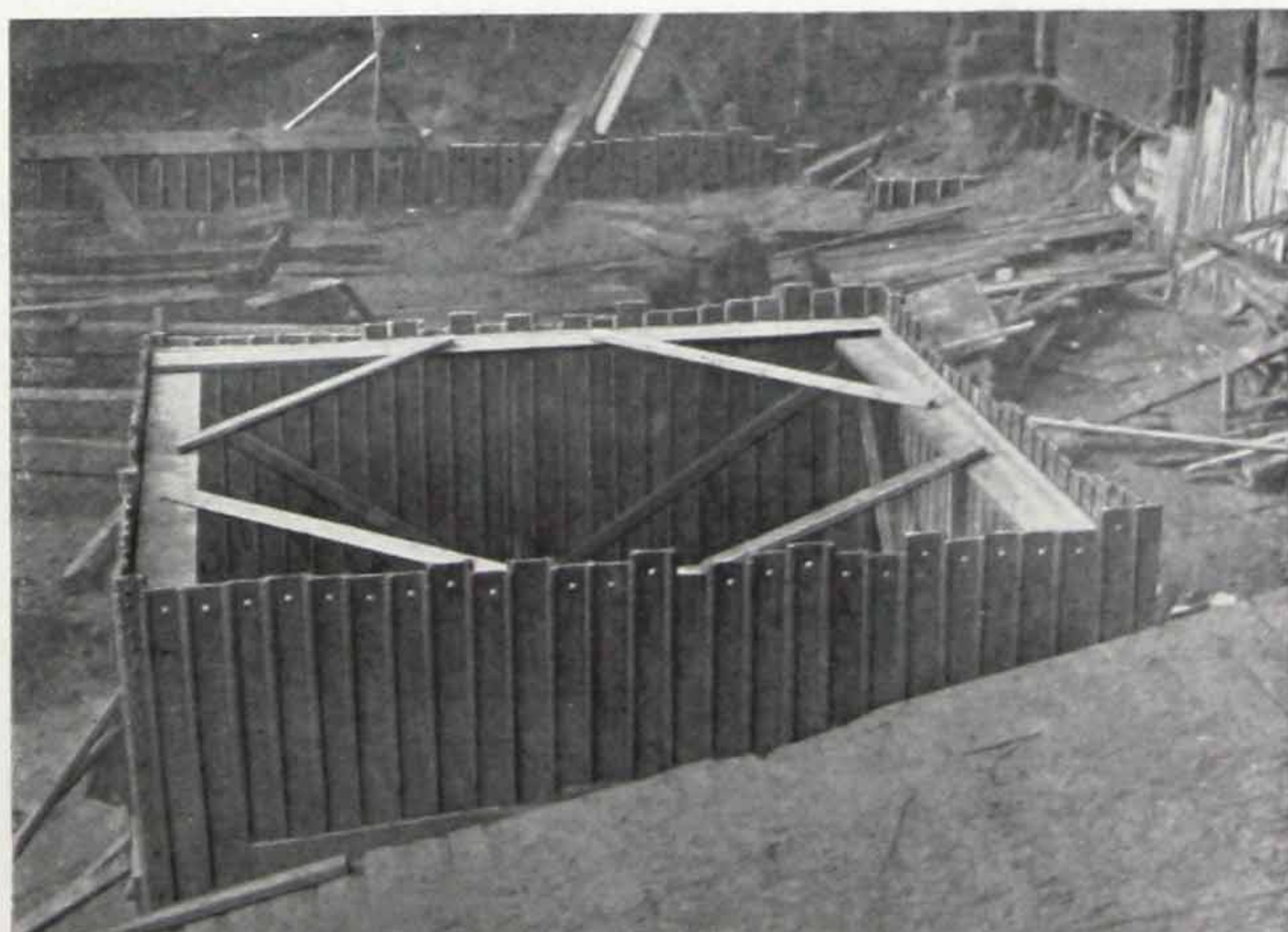
Inverted McKiernan-Terry Hammer pulling Lackawanna Steel Sheet Piling, Lexington Avenue Subway, New York. The method of attaching to the sheet piling section is shown in the detail view, and the larger picture shows how the shackle is attached to special plates which are bolted to the lower half of a spliced piling section, utilizing the splice plate holes for the bolts.

A method of using an inverted steam hammer to pull deep-driven Lackawanna Steel Sheet Piling in connection with Harlem River Subway work, New York City, is shown on this page. This idea was conceived by N. R. Melvin, Superintendent for McMullen & Hoff, the contractors, as a means of greatly reducing pulling costs.

A steel strap about 4 in. wide was passed entirely around the hammer over the anvil blocks and fitted with a simple shackle at the upper end (lower end in pulling). The 3½-in. space on each side of the strap was occupied by other straps to provide attachment to the derrick. In pulling, the inverted hammer took hold of the pile by means of a shackle, and the derrick was then caused to pull upward. This pulled the center or shackle strap down upon the anvil block, and the hammer was started working. The hammer used, 11 x 11 x 56-inch, weighs 1500 pounds, has 7-inch cylinder bore and stroke, and is fitted with a 200-pound ram. Its normal speed is 300 strokes per minute.

On this job piles penetrating 26 feet in clay, sand and gravel ("ordinary hard pulling") were withdrawn in from 2 to 10 minutes each.

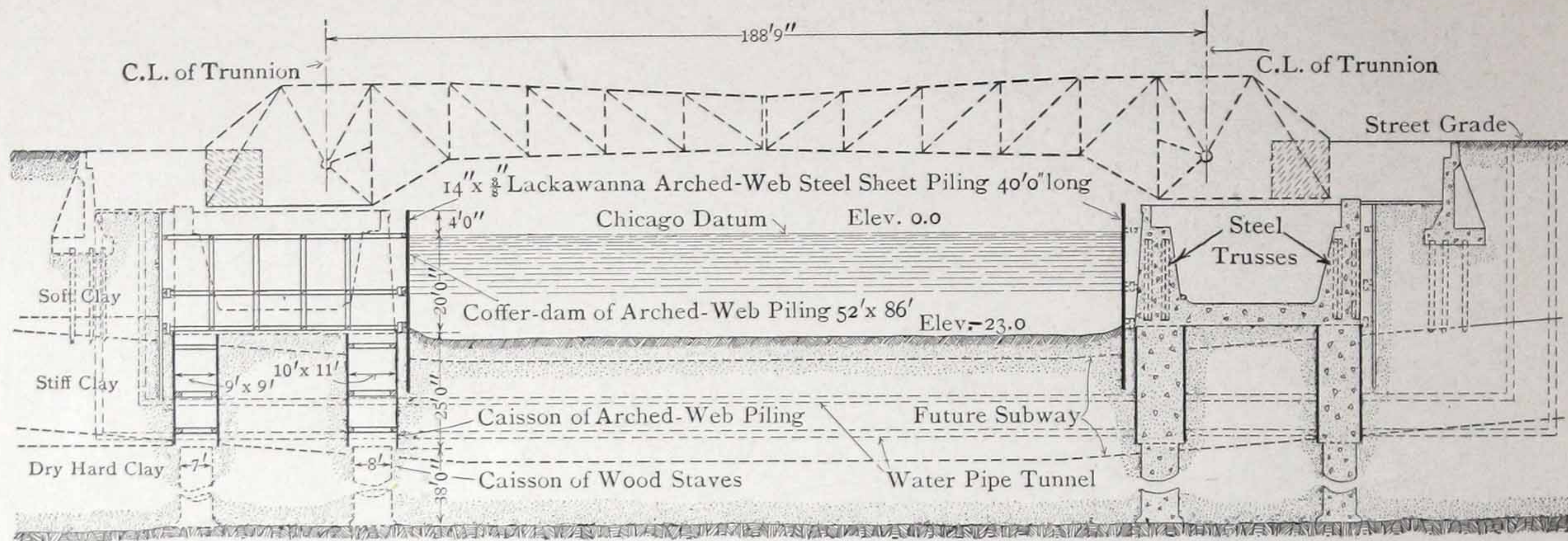
Concrete should never be applied directly to steel piling that is to be pulled, as the concrete and steel firmly bond together. Where concrete is essential, it can be separated from the piling by thin wooden sheeting.



Lackawanna Steel Sheet Piling Cofferdam used in excavating the site of a sub-foundation for machinery. After foundation was completed the piles were pulled and sold for re-use.

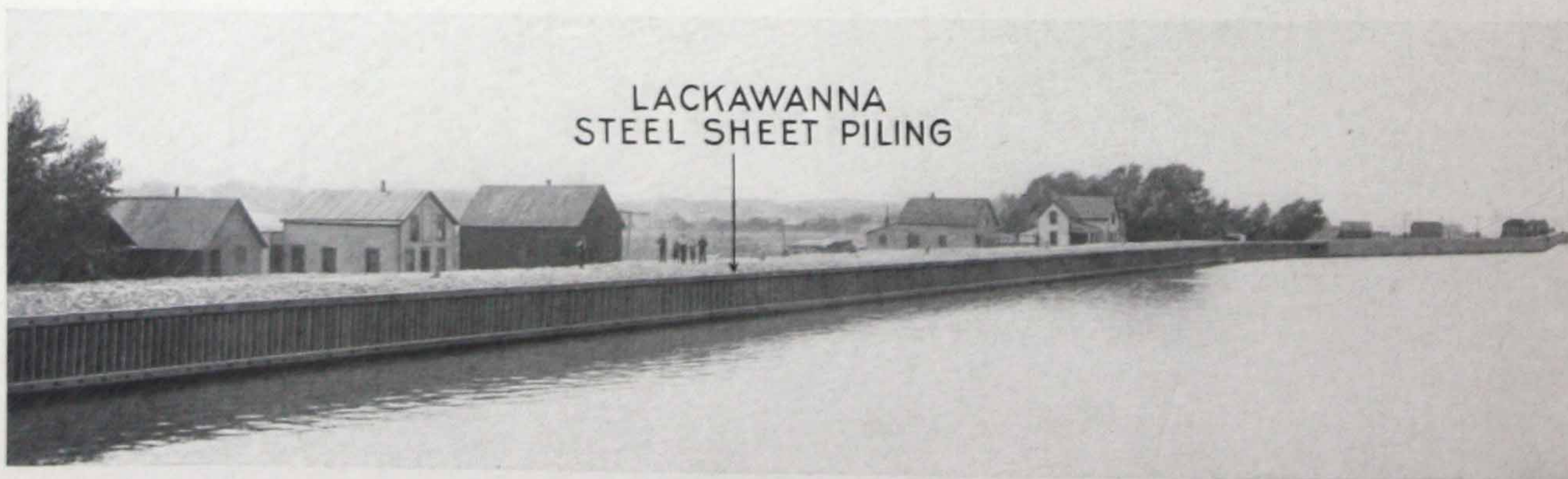
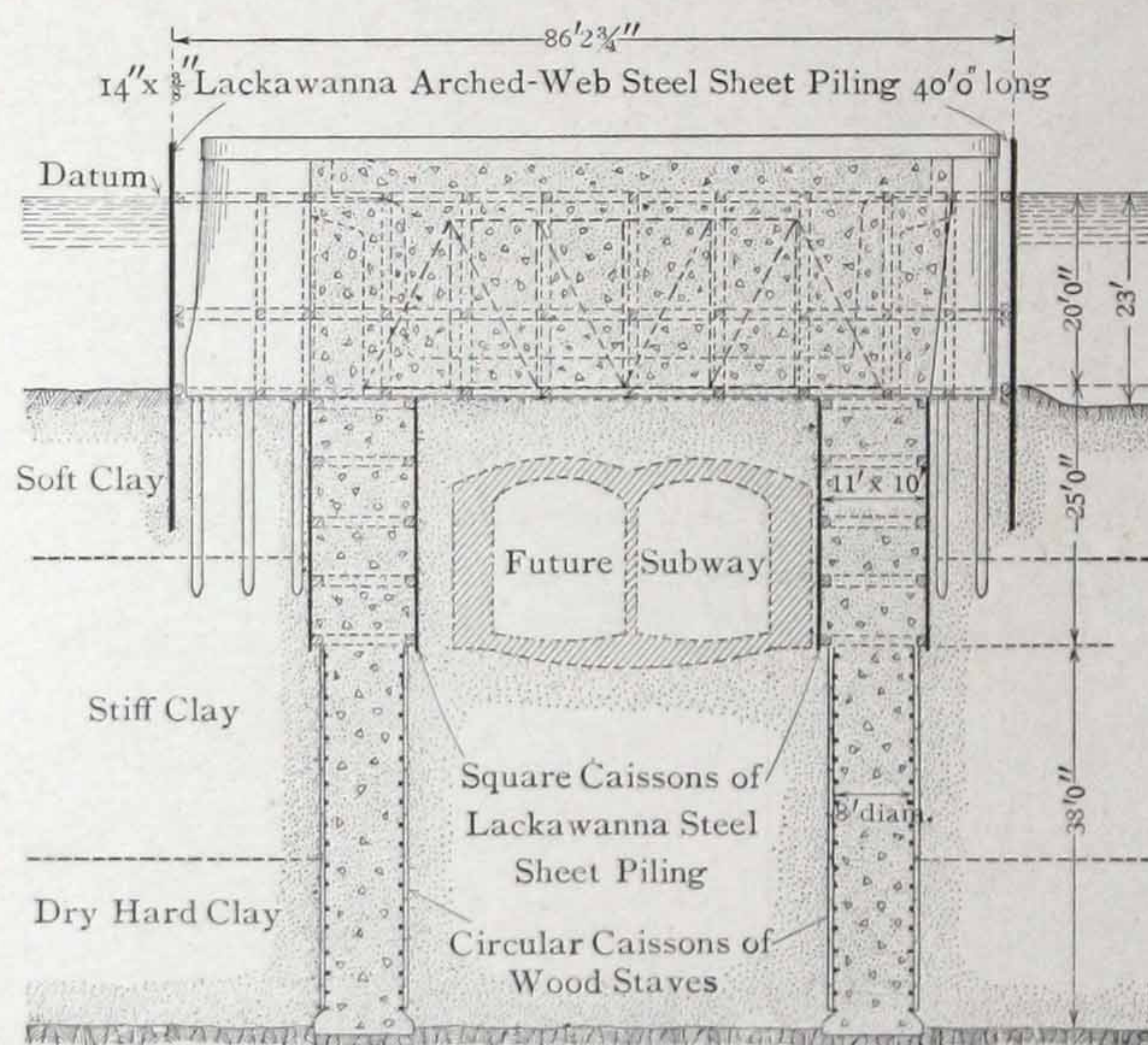


Lackawanna Steel Company



Cofferdams and caissons of Lackawanna Steel Sheet Piling utilized in constructing foundations for the Chicago Avenue Bridge, Chicago. Each large cofferdam, 86 feet by about 56 feet, was driven with 40-foot lengths of 14-inch by $\frac{3}{8}$ -inch Lackawanna Arched-Web Steel Sheet Piling on three sides and wooden sheet piling on the fourth.

Inside each large cofferdam, four smaller ones, for the upper portion of the caissons at corners of the abutment, were driven to water level, and then followed down to the required position, 20 feet below datum. The large cofferdam was then braced, excavated, pumped out, and this work continued in the four small steel sheet pile caissons. The bracing was placed as excavation progressed, to 45 feet below water level, at which point the clay became stiff enough to allow continuation of the excavation within circular caissons of wooden staves to bedrock 83 feet below datum. These four caissons were then filled with concrete.



1,135 feet of Lackawanna Steel Sheet Piling permanently installed at a cost lower than for timber for the same work. The steel is also much more durable than timber in both fresh and salt water.

Lackawanna Steel Sheet Piling



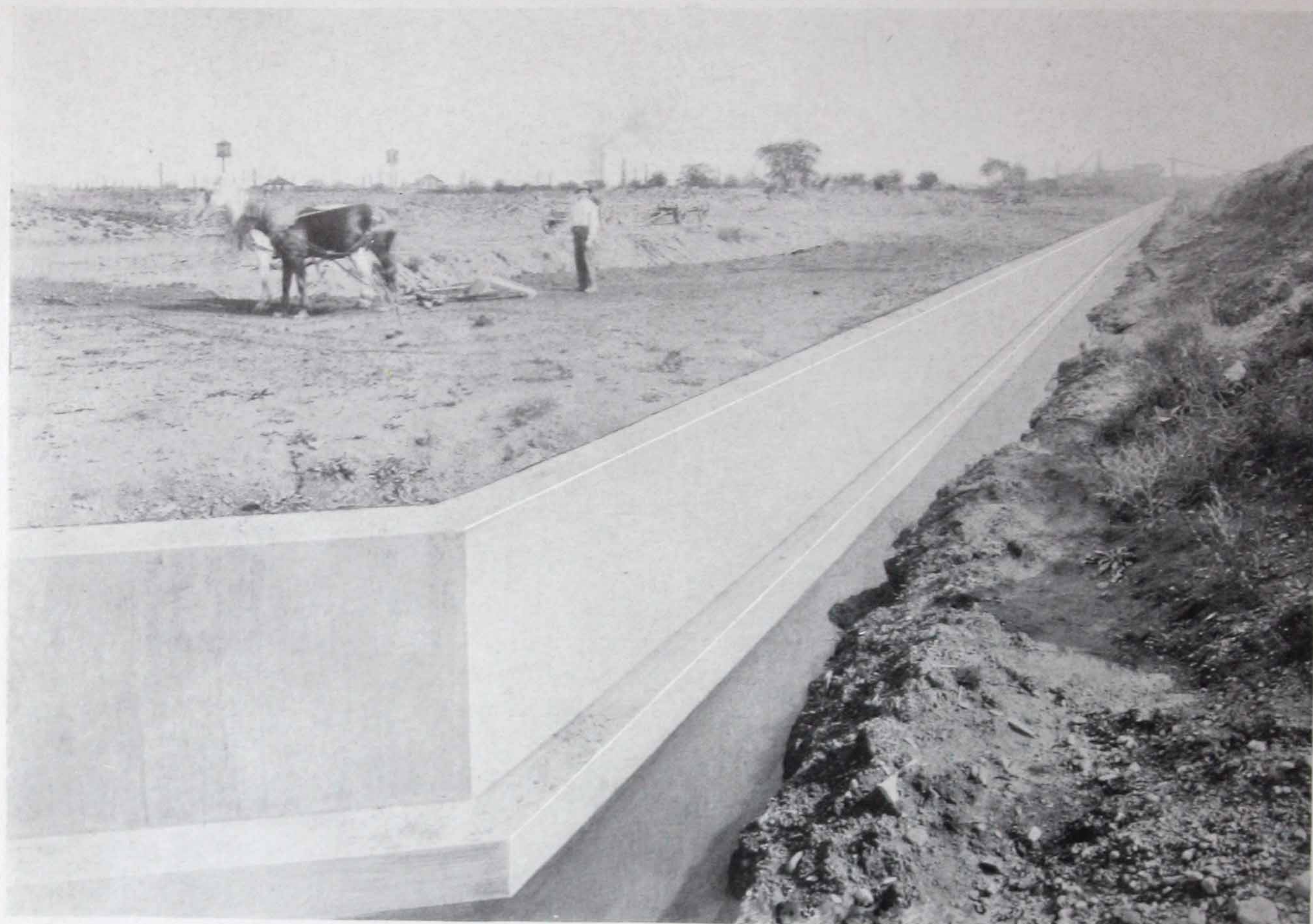
Permanent dock and bulkhead wall of Lackawanna 14-inch Arched-Web Steel Sheet Piling. Built by the United States Government as part of the improvement of Black Rock Harbor, Buffalo, N. Y.

The tie rods and anchors which support the wall are well shown here. Extreme regularity as well as strength of the sheet piling is characteristic of the entire 1,135 feet of wall in this work. The cost was actually less than for pile and timber walls, which latter would also have been inferior in every way. A front view of this wall is shown on the title page, and others at the bottom of pages 13 and 58.

Resistance to corrosion in permanent installations

THE exposure of steel sheet piling above or below the ground level, to continuous or intermittent wetting from surrounding water or earth, or from rain and snow, as well as to chemical action from the acids contained in materials with which the piling is brought into direct contact, is not an important matter on temporary installations, but in permanent work the steel sheet piling can, in most cases, be given sufficient protection against the corrosive elements encountered by giving it at least two coats of good preservative paint.

The rate of rusting would of course depend largely upon the nature of the soil and exposure. Experience seems to indicate that steel in deep penetration is not subjected, throughout the lower portion at least, to any serious amount of free oxygen, and consequently does not rust seriously. Piling driven into ground under water does not seem to deteriorate further after once a light covering of rust has formed. However, as some corrosion of any steel sheet piling may reasonably be expected where the metal is exposed, protective measures are most desirable on all permanent installations. Completely encasing the pile in concrete offers perfect and permanent protection against corrosion.



The Lackawanna Protected-Steel Sheet Piling dock wall at the Rome Terminal of the New York State Barge Canal. What appears to be mass concrete is in reality the line of steel sheet piling with the top eight feet encased in concrete. So accurately did this steel sheet piling drive to the true line that in the entire length of 900 feet, the front and back faces of the wall, although only 14 inches apart, are absolutely parallel and in straight line throughout. The earth in front of the wall is to be dredged out to a depth of 12 feet. See photographs on pages 24, 25 and 61.

Lackawanna Protected-Steel Sheet Piling

LACKAWANNA Protected-Steel Sheet Piling, patented by us, consists of standard Lackawanna Sheet Piling sections *with a concrete facing so formed and mechanically and adhesively bonded to the steel sheet pile as to permit driving of the pile with the protective concrete facing attached.* With this construction, not only is the metal thoroughly protected, but such piles can be economically used in permanent work, in competition with timber, stone or concrete in certain classes of constructions, giving full protection

against corrosion, increased permeability, strength and finish to the wall.

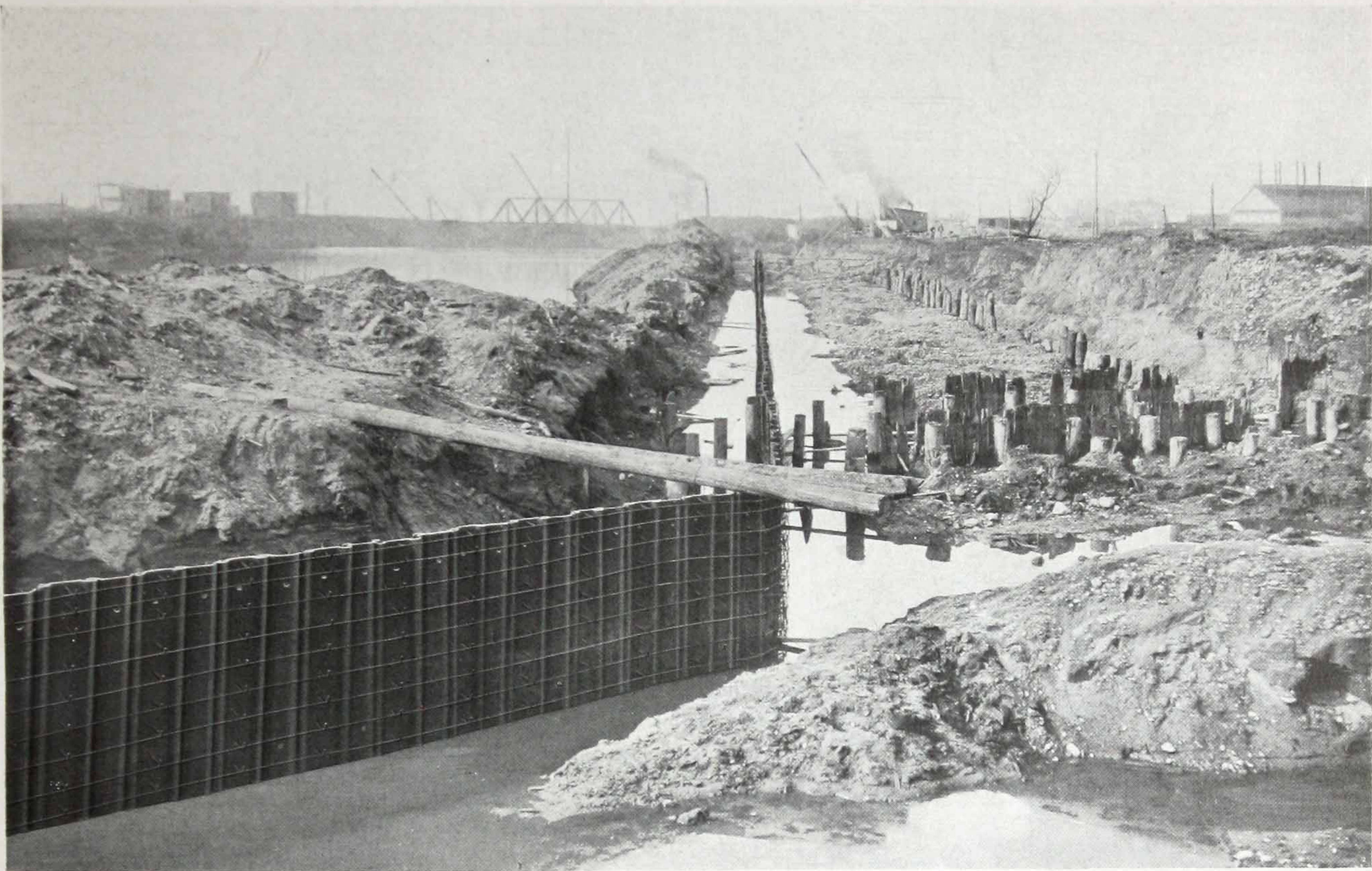
The protected piling can be made with Lackawanna piling bars of various weights, the modulus of the different steel sections varying, to give the required lateral strength to meet different conditions and lengths of the vertical piling beams.

Such protected piling is especially suitable:

(1) For sea walls or retaining walls built on soft material, which would otherwise call for submarine work in sub-foundations of timber, stone or gravel;

(2) For walls where, during construction, it is necessary to carefully refrain from disturbing

Lackawanna Steel Sheet Piling



The wall of Lackawanna Steel Sheet Piling in the Rome Terminal of the New York State Barge Canal, at the time when the tie bars and rods were placed to hold the protective concrete on the top eight feet of wall. $\frac{3}{8}$ -inch rods inserted in holes spaced 8 inches apart vertically and punched in the center of the web of each sheet piling section hold the longitudinal rods in place. The material at the left of the wall was taken out to a depth of 12 feet by hydraulic dredges. See also photographs on pages 24, 25 and 60.

adjacent structures, as levees, old dock walls, building foundations, railroad embankments, etc.;

(3) Where the question of ground water, underlying material, small available working area, or economy of time, render the ordinary type of mass concrete or timber walls undesirable;

(4) Where the earth, water or air surrounding the structure is permeated by acids, or conditions causing *extreme corrosive action*, which would tend to reduce the period of life of the ordinary type of *unprotected* steel sheet piling;

(5) Where quick action is required in the construction or repairs of permanent foundations, levees, dikes, canal, river or coast revetments, where strong and impervious walls are required above and below the surface.

A permanent installation of Lackawanna Protected-Steel Sheet Piling in above or similar con-

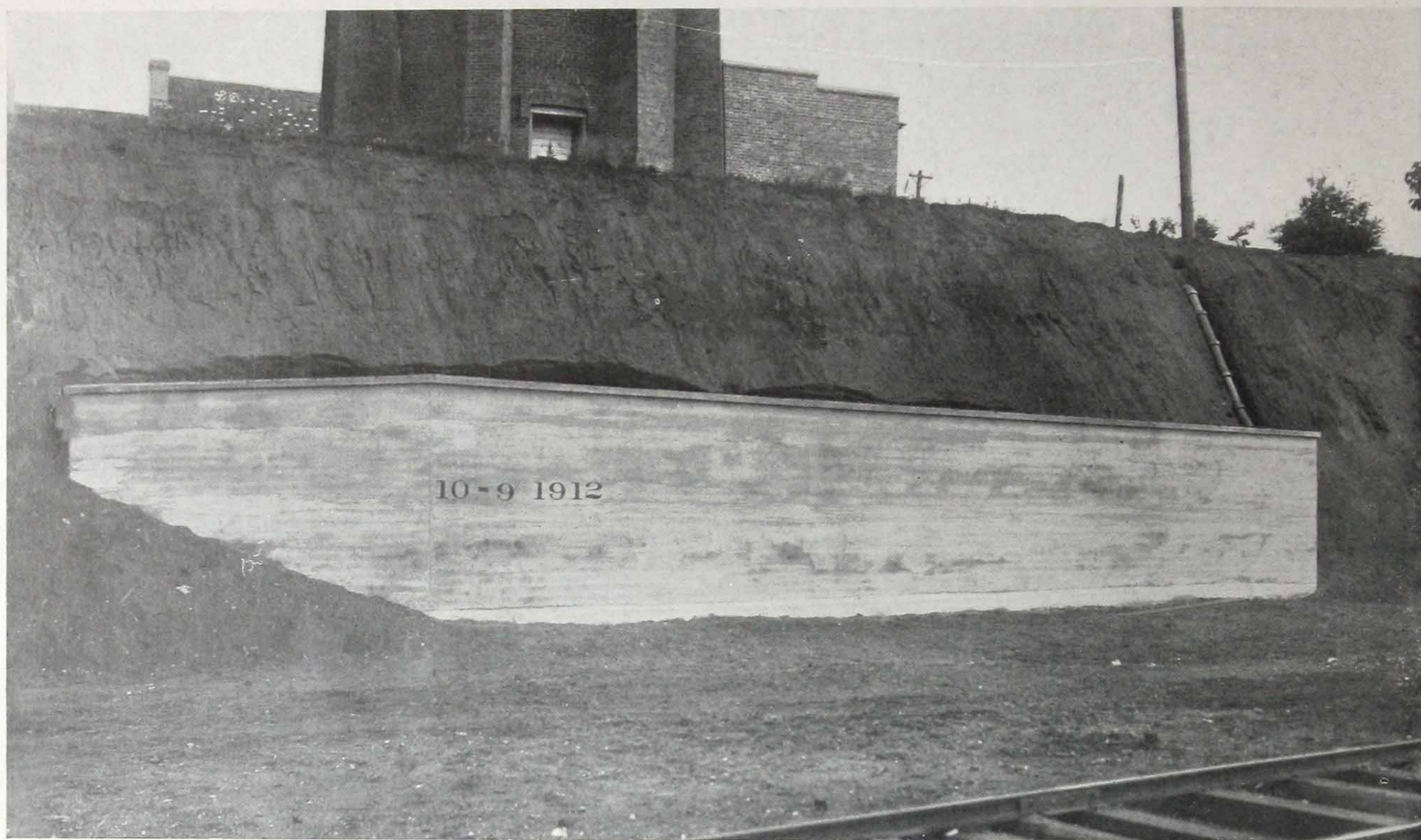
structions has further advantages:

(1) No sub-foundation is required, as both sub-structure and superstructure are integral and installed at one and the same time.

(2) No submarine excavation or work is necessary, as the complete installation of the piling can be carried on from above the surface without disturbing underlying conditions or adjacent constructions.

(3) The piling wall has a comparatively narrow width over all, throughout its vertical height, thus allowing it to be driven and finished in contracted areas, either above or below the surface.

(4) Exposure to the action of waves, tides or currents, as in levees, sea walls, shore revetments, etc., does not necessitate riprap or stone filling along the bottom of the outer face. The protected piling forms a sub-curtain wall, presenting at all



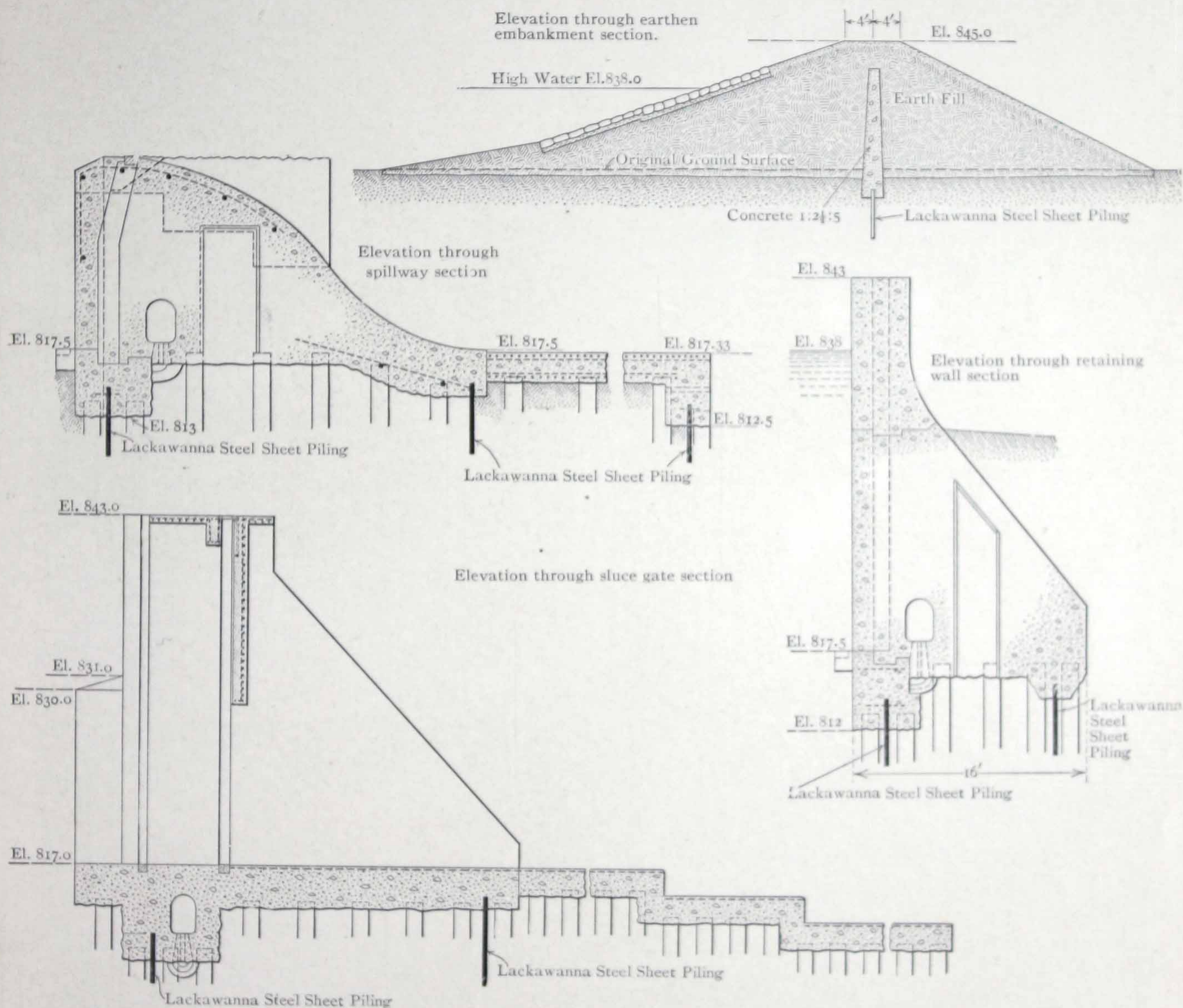
Permanent retaining wall of Lackawanna Protected-Steel Sheet Piling driven to hold and protect bank in which rests the foundation of a large smokestack. The steel sheet piling wall above and for some distance below the surface is encased in concrete. Such a wall is simple to erect, practically indestructible, neat and never weakens.



Coon Rapids (Minn.) Dam protected by cut-off walls of Lackawanna Steel Sheet Piling as shown on next page.

Lackawanna Steel Sheet Piling

Underneath its entire length of 2,070 feet the concrete dam at the Coon Rapids hydro-electric plant, six miles above Minneapolis on the Mississippi River, is protected from seepage and underscoring by two parallel watertight cut-off walls of Lackawanna Steel Sheet Piling, embedded in concrete at the top, and at the bottom penetrating at least five feet into impervious soil. (See picture of dam at bottom of opposite page.) The elevations below indicate the position of the steel sheet piling walls.



times a continuous impervious face to the action of the water throughout the entire length of the piling, and absolutely preventing the passage of water through or under the wall, and consequently under-scouring.

(5) The steel substructure and superstructure being integral, give great strength. At the same time the wall may be sealed into a practically

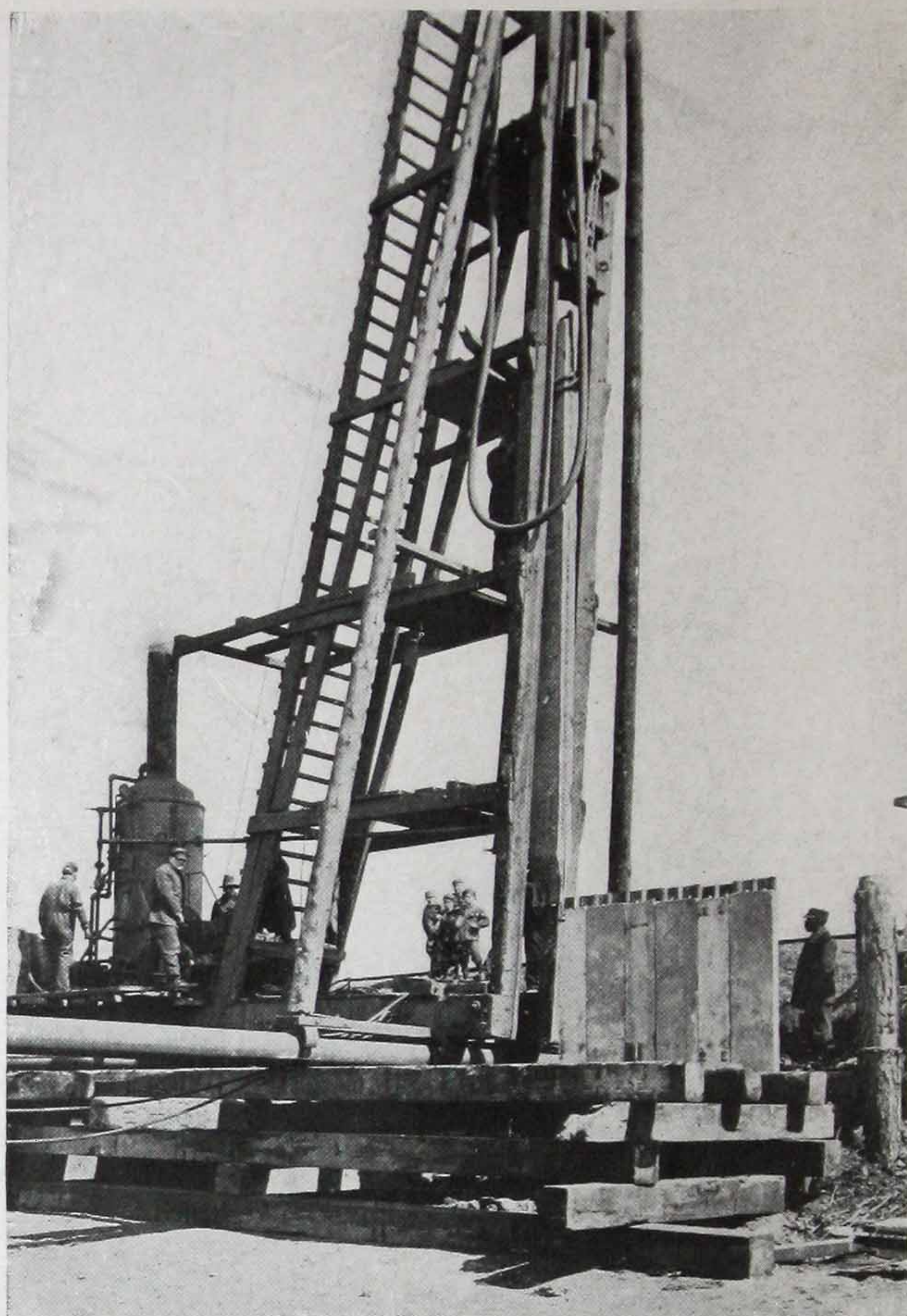
continuous mass, yet built in small separate conveniently-handled units.

The handling and driving of the protected piling is much the same as with the unprotected piling, though the use of a steel driving cap is necessary and a steam hammer preferable. These protected piles interlock in the same manner as do the unprotected piles and the strength and flexibility



of the steel interlocking joint is the same. Similar curves and angles may be made in the wall as called for. The pockets, formed in the edges of the concrete facing and in the interlocking steel joints are, after driving, poured with cement grout, which strongly and rigidly seals together the different units comprising the wall. After a section of the wall has been driven and the sealing pockets grouted, a continuous cap of concrete is placed on the top of the piling, thus completely enclosing the steel, as well as giving additional strength and pleasing finish to the wall. Where conditions warrant, that portion of the naked steel which penetrates the ground below the atmospheric line need not be protected, but can be coated with good preservative paints; after the steel thus coated has been completely driven, the upper portion can be encased in concrete in one operation by the use of removable forms, the same mechanical bond of tie bars, etc., being used.

The following pages illustrate practical forms of protected piling, based upon the application of the concrete protection to standard Lackawanna



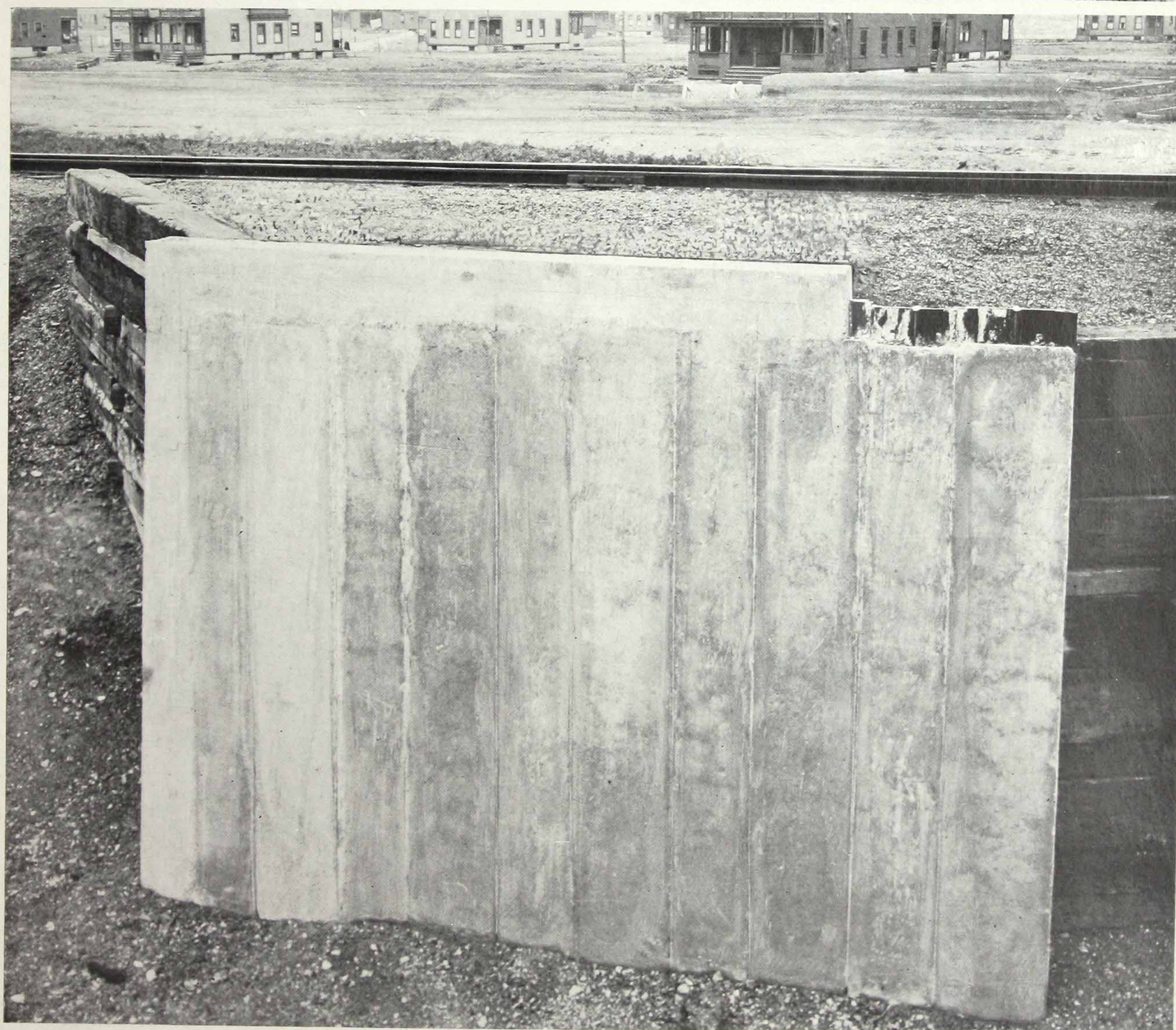
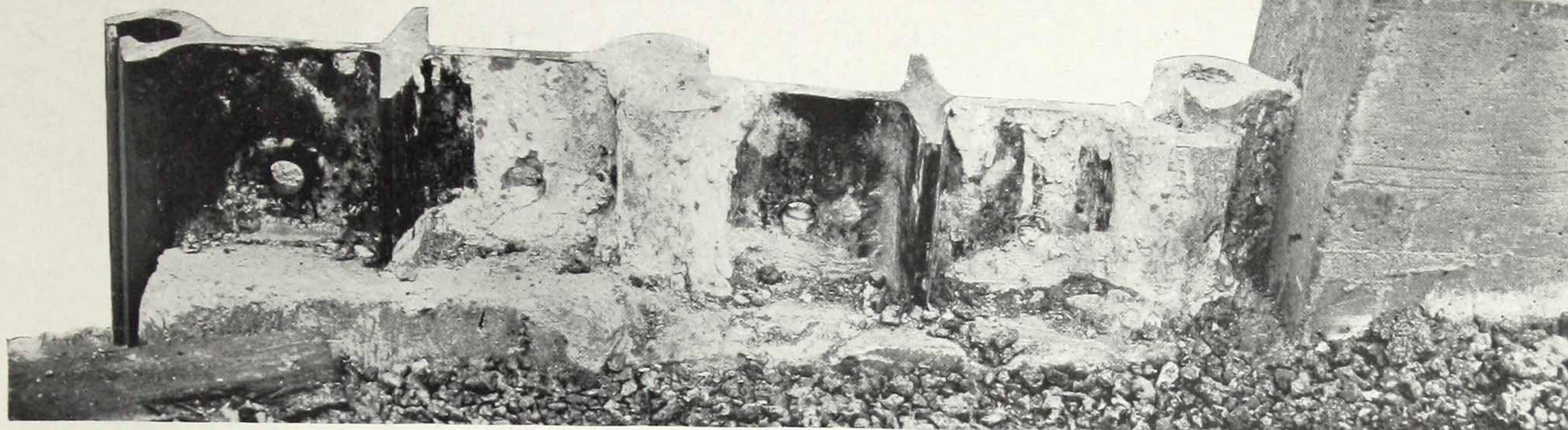
Entering a Lackawanna Protected Piling Section into the adjacent interlock preparatory to driving.



A group of Lackawanna Protected-Steel Sheet Piling Sections driven, and one (in the foreground) which has been driven and pulled twice.

Lackawanna Steel Sheet Piling

Unfinished top of wall showing two piling sections exposed. Interlocks grouted and ready to receive the continuous finishing cap (to the right), which may be designed for ornamental effect, walk, etc.



Section of wall built from Lackawanna Protected-Steel Sheet Piling, showing continuous cap, and at right the interlock grouted ready for application of cap.



Center-Flange, Arched-Web and Straight-Web Steel Sheet Piling bars. It will be noted that the bond between the steel and concrete is in all instances strengthened by the use of tie rods.

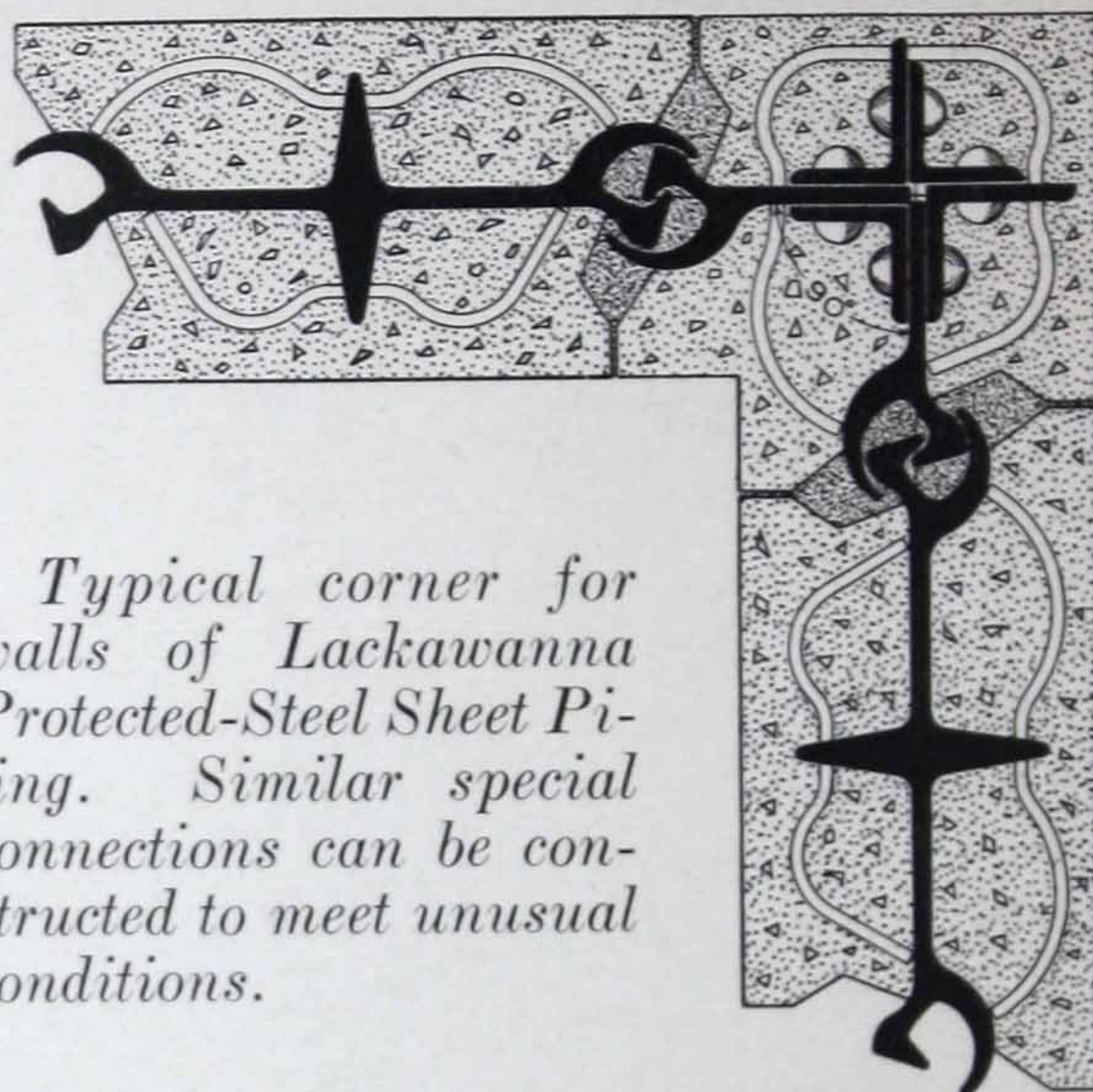
The tie rods for the single bar slabs containing Center-Flange piling are bent to proper shape and passed through holes punched in and near the outer edge of the center flanges of the piling bar. The rods are inserted with their curved ends upward and then turned down until the ends engage and slightly bind on the web of the pile on one side and the base of the larger joint member on the other.

The Arched-Web and Straight-Web sections offer no convenient projection through which to pass the rods, so the web at the center is punched with rectangular holes, through which are inserted rectangular tie bars having circular holes in their ends. Through these holes are placed tie rods somewhat similar in shape to those in the Center-Flange section.

The mechanical bond between concrete and steel in slabs containing a number of piling sec-

tions or in continuous walls can be strengthened best by the use of continuous tie rods extending over two or more piles.

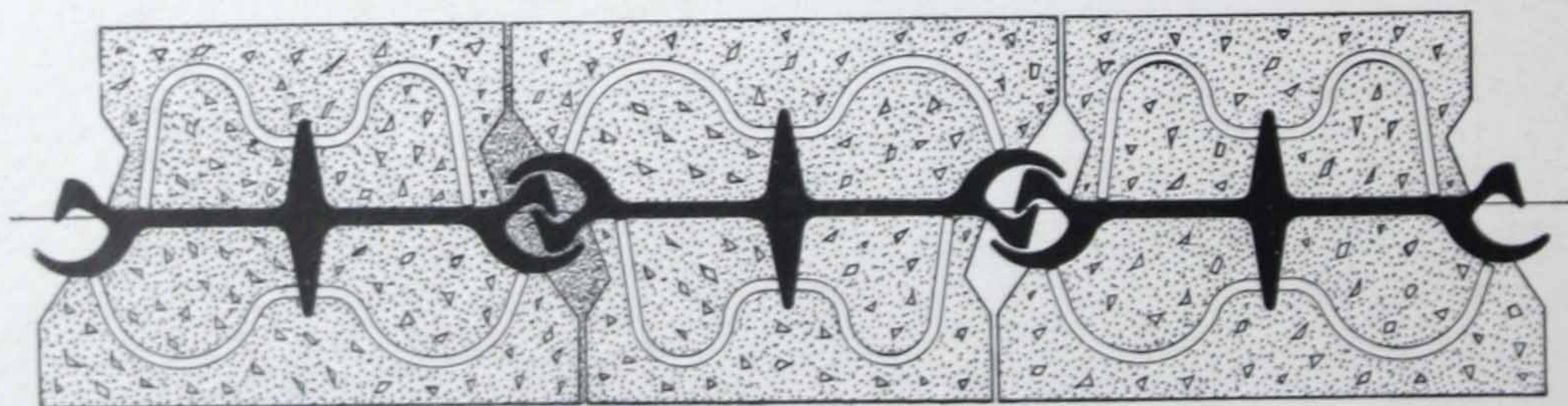
Directions for applying the concrete and for making suitable forms for this work are given on pages 68 and 69.



Typical corner for walls of Lackawanna Protected-Steel Sheet Piling. Similar special connections can be constructed to meet unusual conditions.

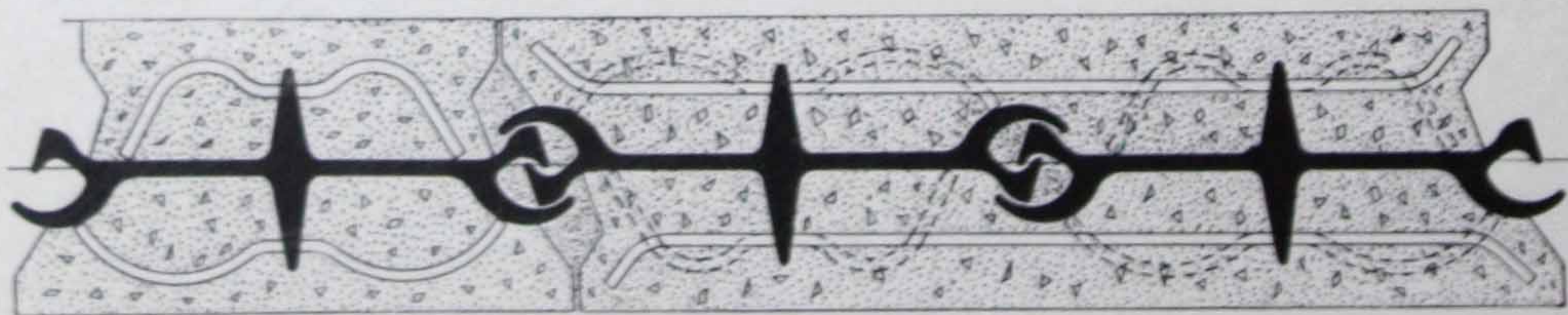
Typical construction details of walls of Lackawanna Protected-Steel Sheet Piling

1



Wall composed of individual piles of center-flange section type, with $\frac{3}{8}$ -in. round tie rods proportioned for thick (i. e., 12-in.) wall, and showing pockets at interlock before and after grouting. The individual piles with protective concrete facing attached are driven or jetted down and the pockets within and outside of the interlock are then grouted simultaneously. If desired, mud or dirt in these spaces below point of penetration can be blown out by air or water jet before grouting. See note, page 67.

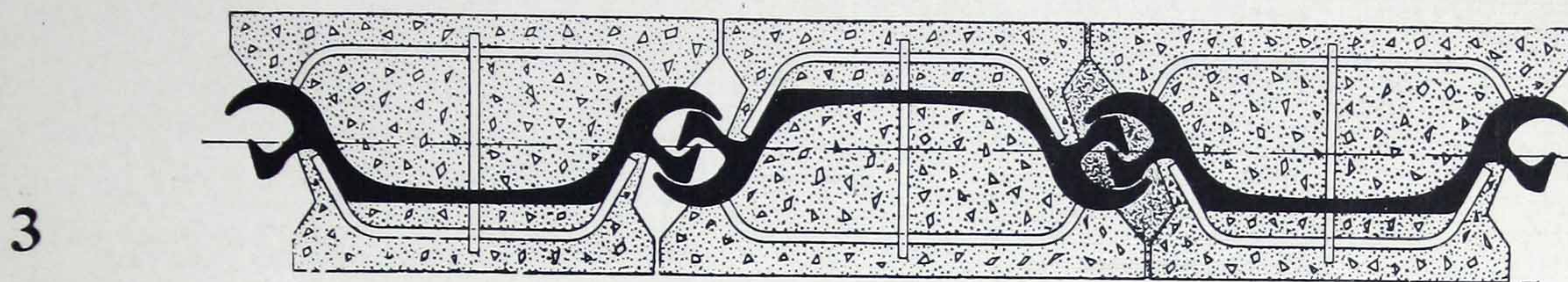
2



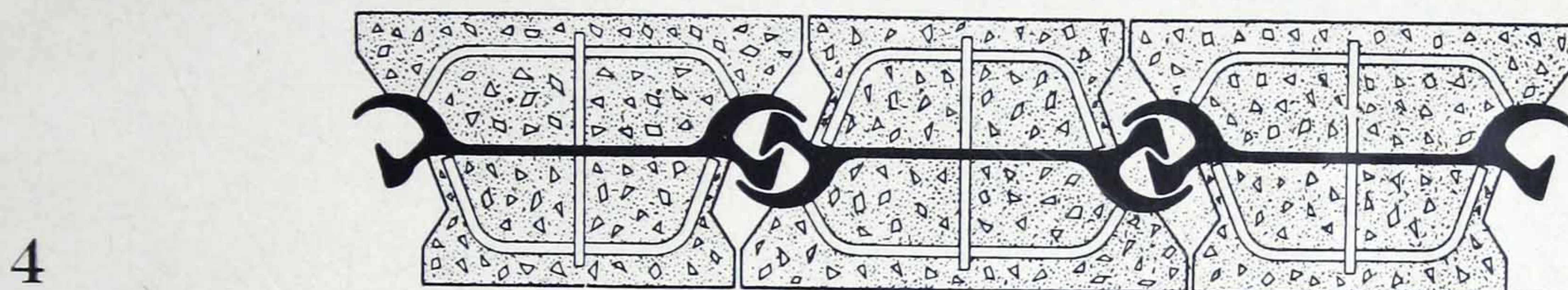
Same as No. 1, but showing that slabs composed of any number of protected piles are interchangeable with individual protected piles as far as the interlocks and grouting

Lackawanna Steel Sheet Piling

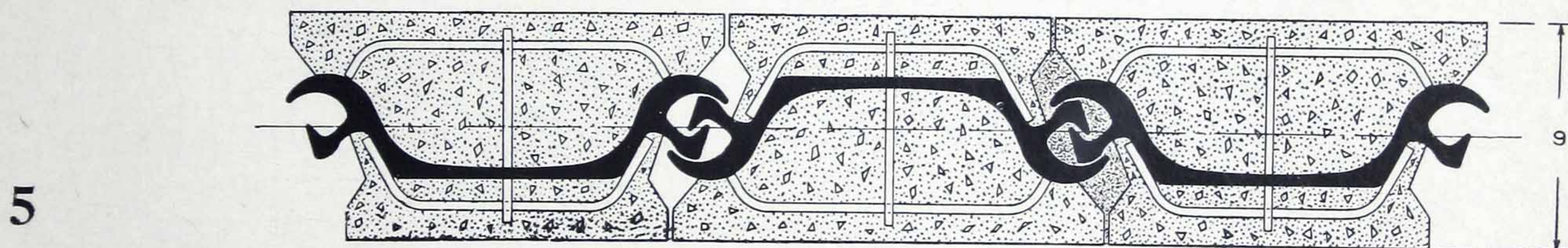
are concerned. The interlocks within slabs can be grouted at the same time as are the joints. The dotted lines show how individual tie rods can be used in the two-pile construction. Where all steel is driven and the concrete placed on the wall afterwards down to point of penetration, long continuous rods can be laced through three or more piles.



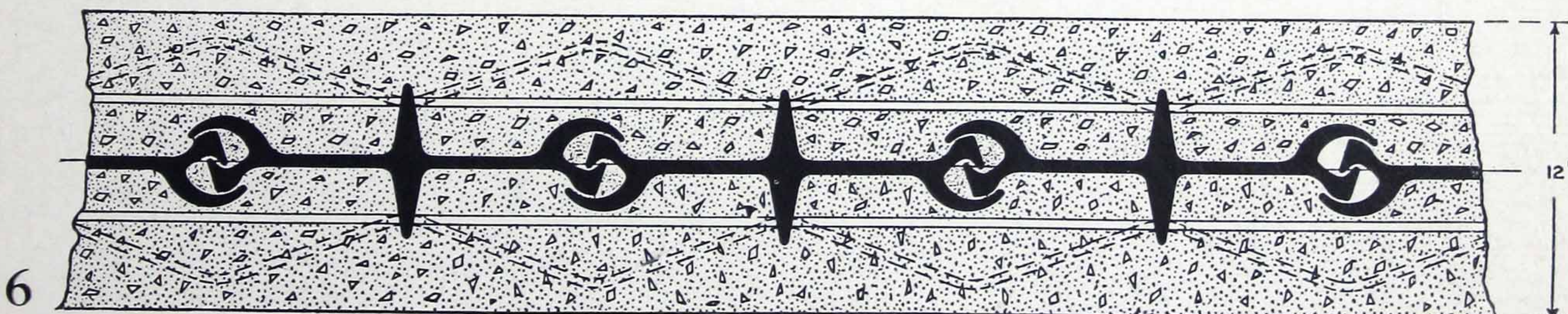
Same as No. 1, but rods and joint proportioned for thin (9-in.) wall. See note below.



Similar to No. 1, but wall composed of individual piles of the straight-web type.



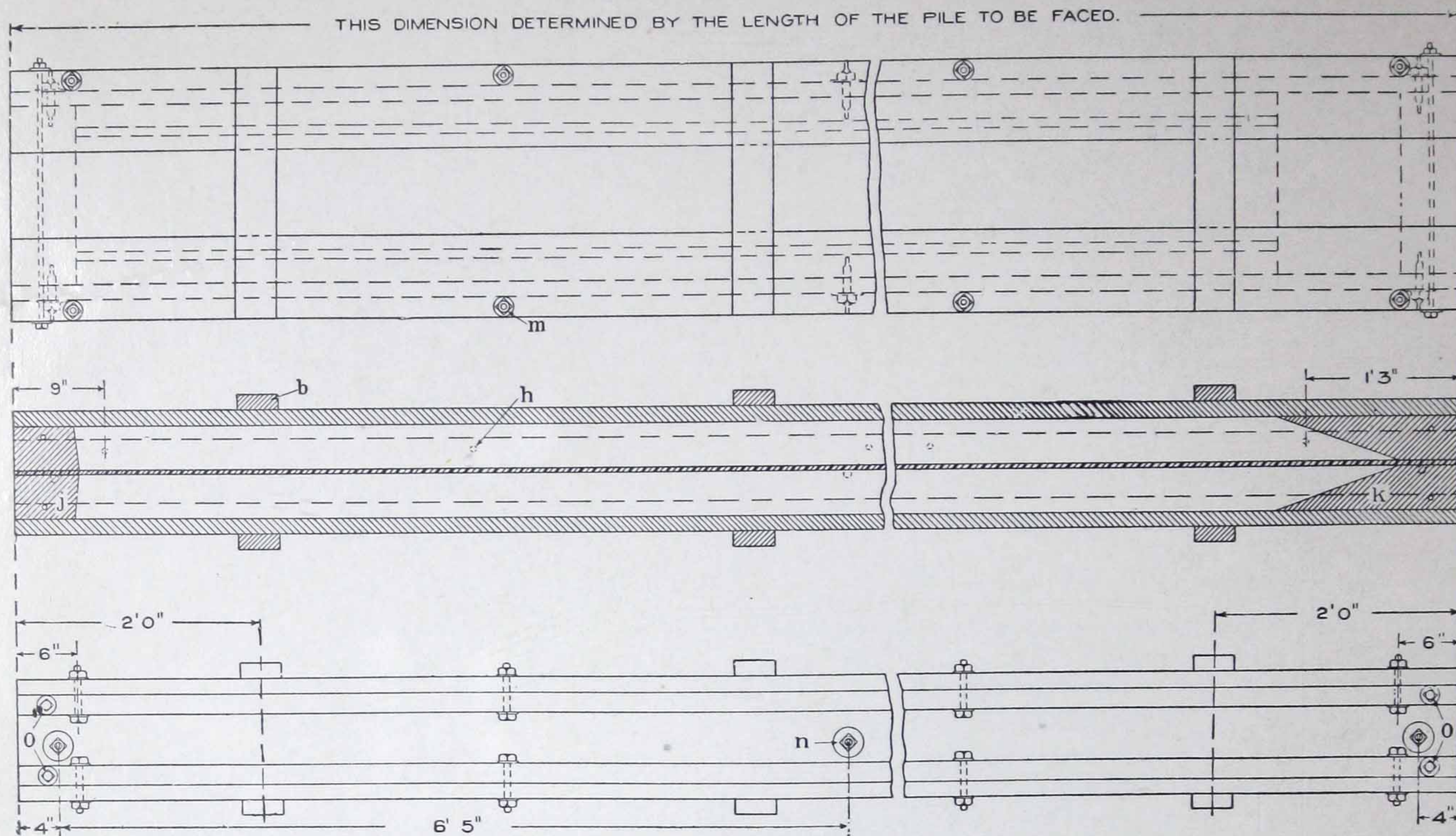
Same as No. 4, but with piles of the arched-web type of section.



Continuous core wall with concrete protection on both faces. Showing two methods of placing $\frac{3}{8}$ -in. round tie rods for binding the concrete to the steel. Straight rods for thin (9-in.) and bent rods for thick (12-in.) walls. Grout within the interlocks prevents harm from expansion and contraction of the steel core. Especially suitable where steel is first driven and the concrete then placed above the point of penetration in one continuous operation. A coating of good protective paint is desirable on the lower portion. The omission of concrete below the point of penetration is permissible only where the corrosive action is greatly reduced.

Note: Where a circular wall is made up of individual piling sections and each turned to an angle of 4 degrees with its neighbors, a curve is produced with a radius of 15.2 ft. for $12\frac{3}{4}$ -in. sections, 16.7 ft. for 14-in. sections and 17.9 ft. for 15-in. sections.

These radii can be produced without changing the form, as clearance on outer edge of concrete facing allows this curvature without direct contact of concrete faces.



Typical form for holding steel sheet pile for the application of concrete protection.

Directions for applying the concrete facing to piles

IN attaching the concrete facing the steel piling is locked in a collapsible wooden form, open at the top. A typical form is shown above. The steel tie bars and tie rods giving the mechanical bond are attached to the pile, and the wooden end blocks giving the required form to the concrete at the ends of the pile are bolted into position in the form. The concrete facing on upper side of pile is then rammed into position.

A mixture of 1, 3 and 5 is suggested for the concrete, using the best of Portland cement, sharp sand and comparatively small aggregates of stone or gravel (not exceeding one inch in maximum diameter). The concrete should be made fairly plastic and enough placed in the form to slightly round above the open top, thus producing the desired compression of the concrete when cover is drawn down by means of holding bolts.

After the concrete has been placed on the upper side and the cover bolted down, the entire form containing the enclosed pile is turned bottom side up; the bottom, which now becomes the top, being removed, the same process is repeated in placing the tie rods and concrete on the other side.

Six inches of steel is left permanently exposed

at the lower end of the pile to act as a cutting edge and facilitate penetration. The concrete above this naked steel cutting edge is given a suitable taper to assist penetration and prevent undue impact on the facing.

Six inches of steel is left *temporarily* exposed at the upper end of the pile. This gives access to the handling holes used in unloading, moving and placing the piles in the leaders of the driver and also permits the use of a steel driving cap. The blows of the hammer can thus be delivered through the cap onto the upper end of the naked steel, and without any direct contact between the hammer or cap and the concrete facing.

All concrete having been placed, the pile is allowed to remain in the form for from twelve to twenty-four hours. The top and sides of the form are then removed, and the completed pile allowed to remain on the bottom of the form for twenty-four hours more. Then it is slid off the bottom onto skids and left until the concrete has set sufficiently that the pile may be handled and driven. These operations require from ten days to two weeks from the time the pile is first placed in the form, depending upon the temperature,

Lackawanna Steel Sheet Piling

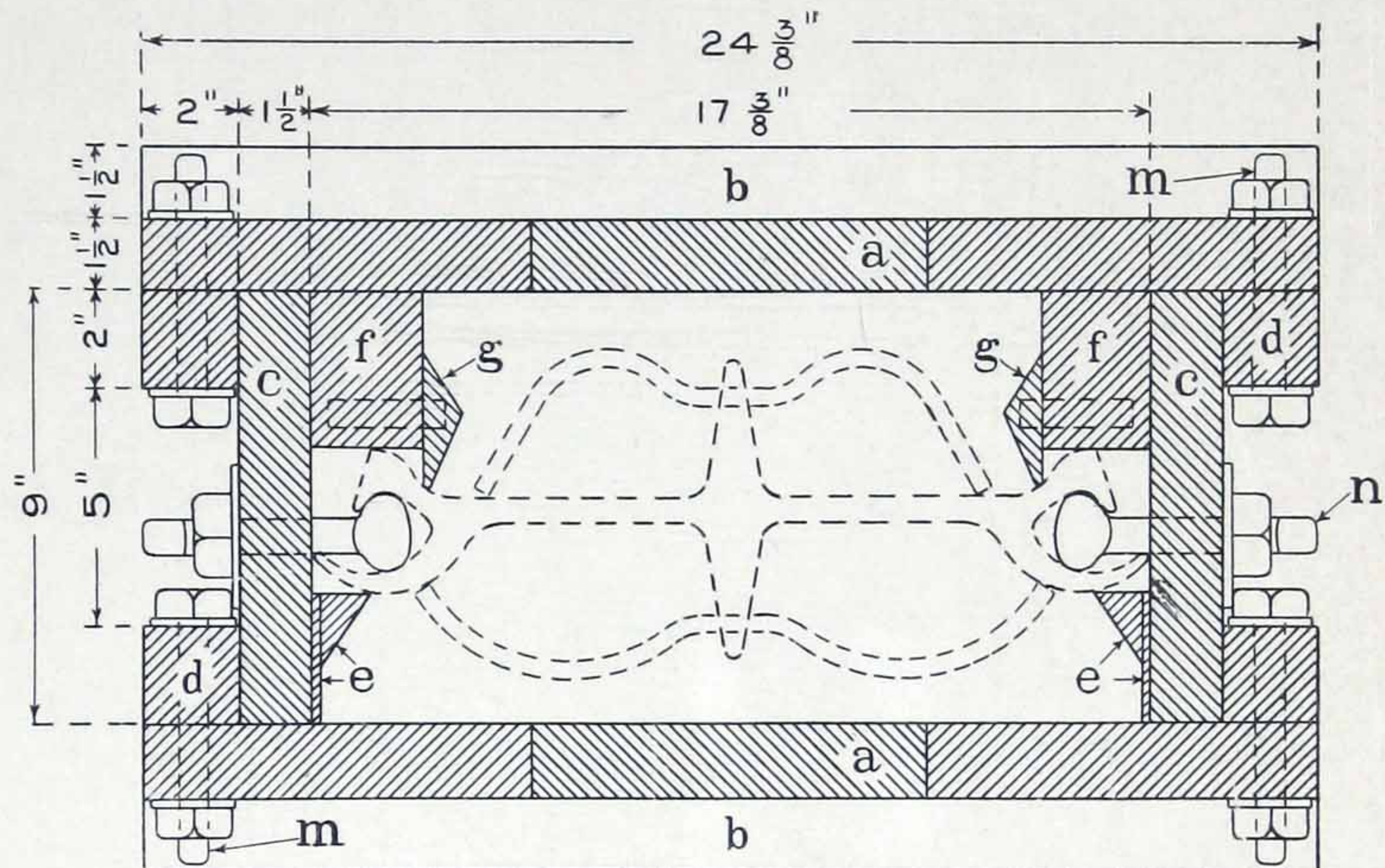
cement used, mixture, etc.

Making extra covers with each form permits re-use of the form (exclusive of the original

bottom) as soon as the pile has been stripped. A greater number of piles can thus be faced in a given time and with the least number of forms.

Construction details of typical form

It is important that all surfaces in contact with concrete must be smooth; preferably machine-planed. All other surfaces need be planed only enough to insure good joints. All outside surfaces may be left undressed. Stock size lumber should be used wherever possible. Forms can be extended to fit any length of piling by lengthening the top, bottom and side planks and the running strips; forms can be shortened by placing the bottom end blocks further in the form.



Cross section of form.

a. Top and bottom of form. Planed to uniform thickness from 2-in. planks.

b. Cleats. 2-in. by 4-in. lumber undressed. Nailed to top and bottom planks. Spaced not more than 4 feet apart in main part of the form.

c. Sides of form. Planed to uniform thickness from 2-in. planks.

d. Side strips. Can be made by splitting ordinary 2-in. by 4-in. lumber into two parts. Must be securely nailed to sides of form.

e. Bottom running strips. Hardwood. In two parts for convenience in making only. Securely screwed or nailed to sides of form. Extend from inside to inside of end blocks.

f. Top running strips. Hardwood. Securely nailed to sides of form. Extend from inside to inside of end blocks.

g. Detachable running strips. Hardwood. Pinned to top bunting strips and extend from inside to inside of end blocks.

h. Pins for detachable running strips. Hardwood $\frac{5}{8}$ in. diameter. Fastened in top running strips, but permit detachable running strips to come away. Spaced not more than 3 feet apart in main part of form.

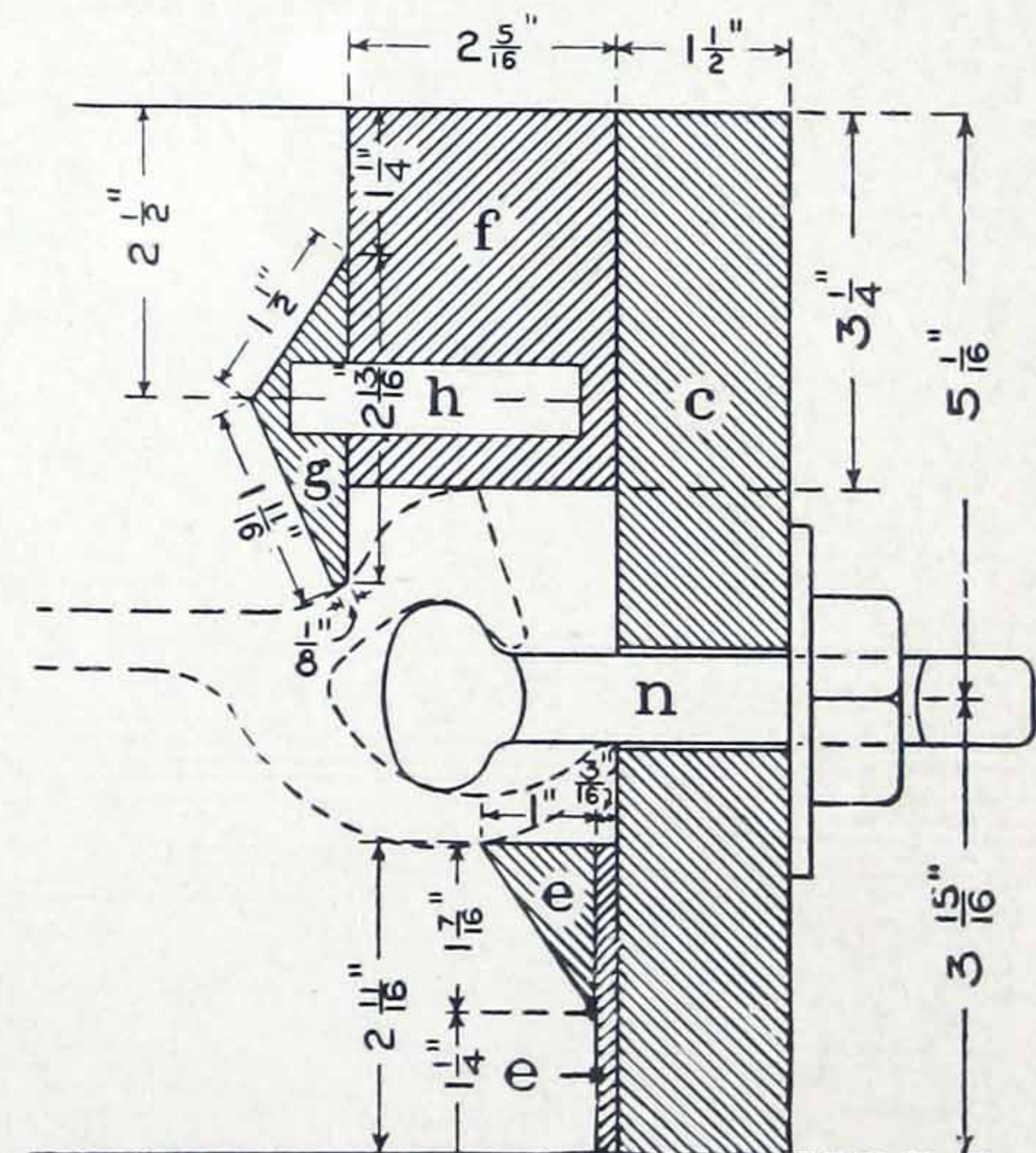
j. Upper end blocks. Hardwood. Different shape for each type and size of piling section.

k. Lower end blocks. Hardwood. Different shape for each type and size of piling section.

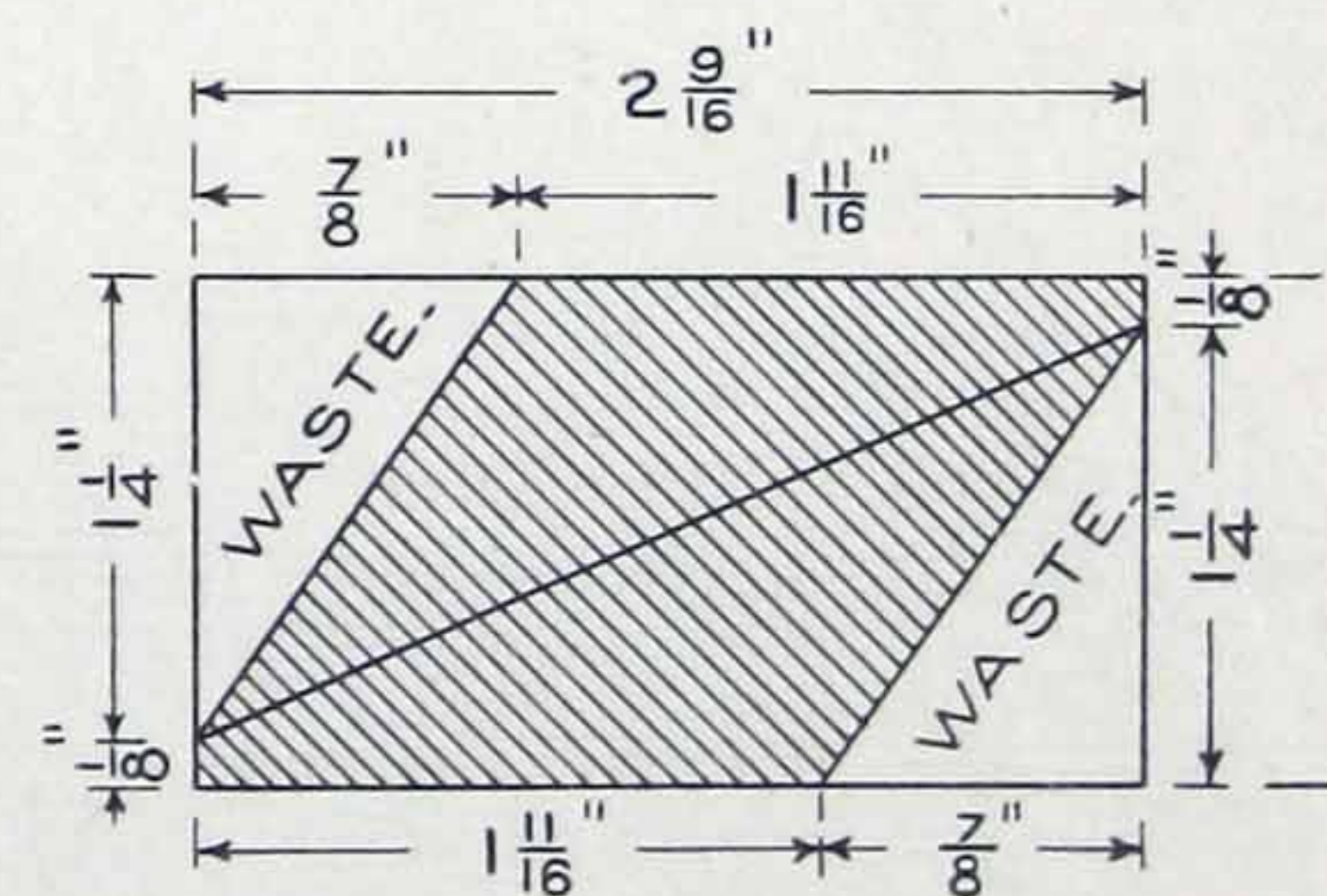
m. Bolts holding sides, top and bottom together. Bolt, $\frac{5}{8}$ in. by 5 in. long in $\frac{3}{4}$ in. hole. Washer, wrought iron, $1\frac{3}{4}$ in. outside diameter and $\frac{3}{16}$ in. thick.

n. Lock bolts for holding pile in position. Bolt $\frac{3}{4}$ in. diameter in $\frac{7}{8}$ in. hole. Head to be flattened as shown. Washer, wrought iron, 3 in. outside diameter and $\frac{3}{16}$ in. thick. To be spaced not more than 8 feet apart in main part of form.

o. End bolts for holding end blocks. Four required. Bolt $\frac{1}{2}$ in. by 6 in. long in $\frac{5}{8}$ in. hole.



Details of running strips.



Suggestion for economical cutting of detachable running strips.



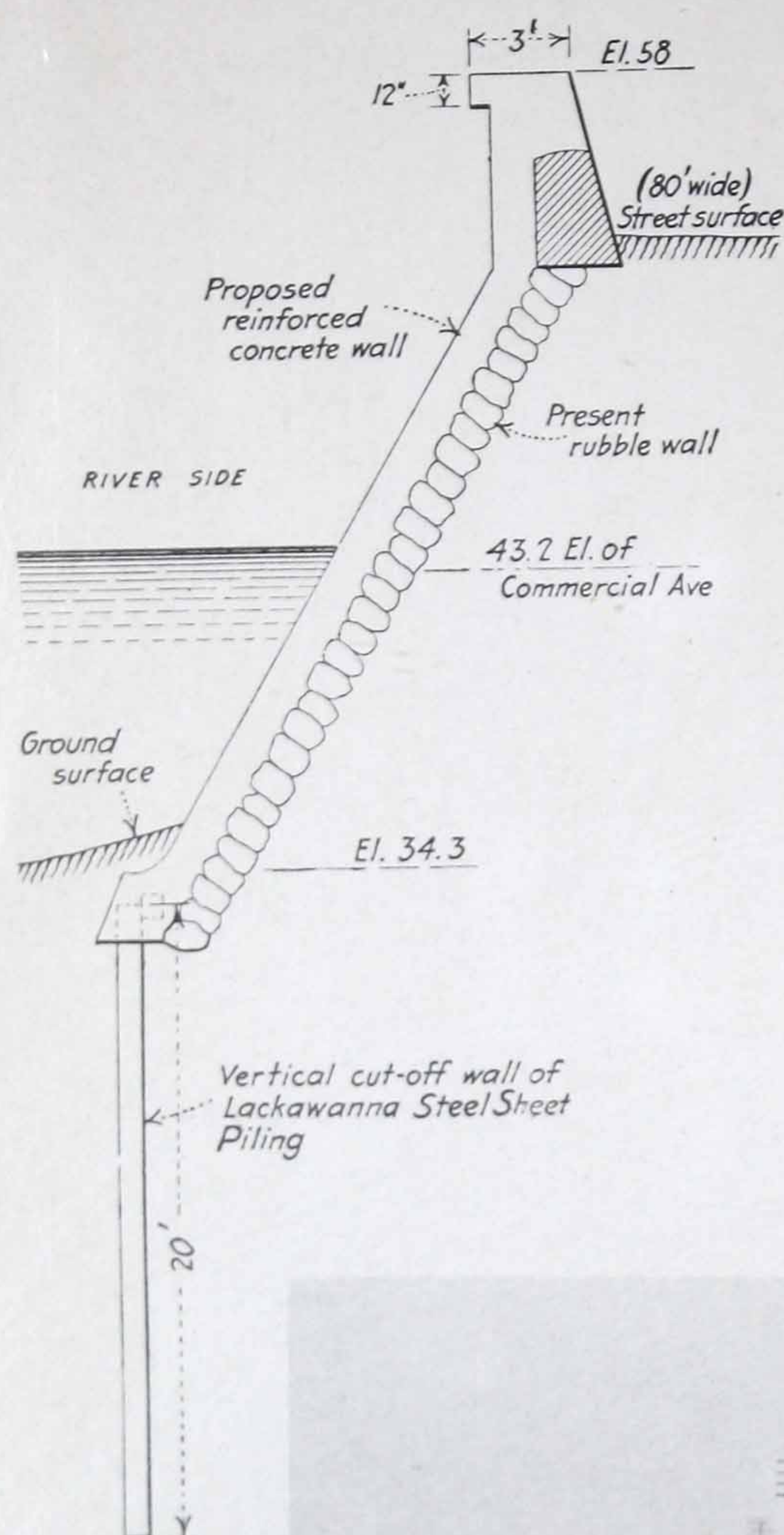
Lackawanna Protected-Steel Sheet Piling in levee work

PUBLISHED data on levee construction, maintenance, repairs and breaks show three principal causes of weakness, which are also direct or indirect causes of breaks or crevasses formed during flood periods.

FIRST—Overtopping; that is, flood waters reaching a height sufficient to flow over the top of the levee, cutting into the top and back slopes of the embankments.

SECOND—Seepage or percolation of flood water through or under the levee embankments, due to excessive hydrostatic pressure, poor material in the bank or underlying foundations, and to holes or openings made in the bank by crawfish or burrowing animals.

THIRD—Poor foundations under the embankments, causing the settlement or breaking down of the superstructure.



Lackawanna Steel Sheet Piling driven as a cut-off wall and reinforcement for the foundations of the enlarged concrete levee constructed in front of Cairo, Ill.

Lackawanna Steel Sheet Piling

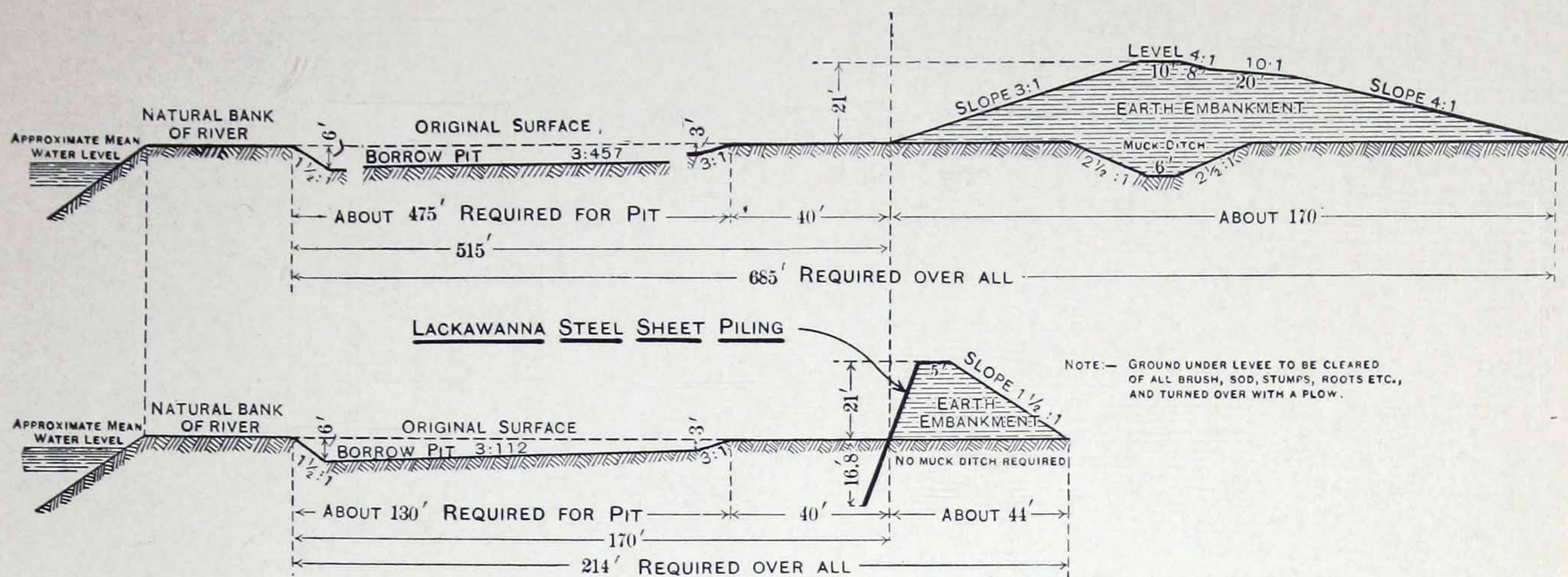


Fig. 1. Cross-sectional comparison of typical earthen levee 21 feet in height, developed from standard sections, with levee of tentative design for same service and based upon the use of Lackawanna Protected-Steel Sheet Piling. In the latter design, the steel sheet piling wall forms a watertight facing on the water side of the levee and a cut-off wall below the same, preventing seepage and percolation through or under the embankment.

This gives absolute protection against damage by crawfish or burrowing animals and at the same time prevents erosion or cutting of the banks by wind or wave action.

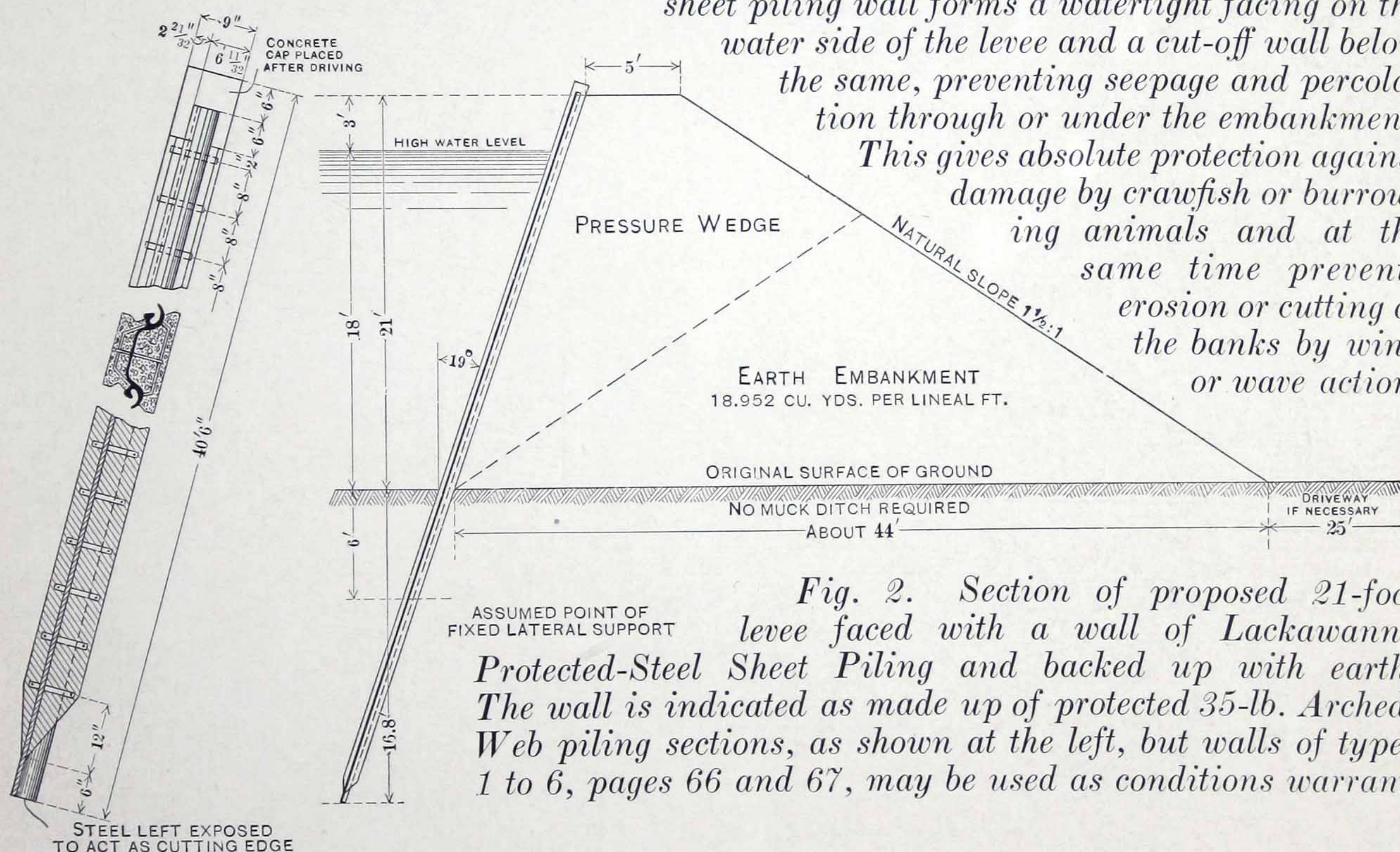


Fig. 2. Section of proposed 21-foot levee faced with a wall of Lackawanna Protected-Steel Sheet Piling and backed up with earth. The wall is indicated as made up of protected 35-lb. Arched-Web piling sections, as shown at the left, but walls of types 1 to 6, pages 66 and 67, may be used as conditions warrant.

Levees heretofore have been constructed almost entirely of earthen embankments, the material being taken from borrow pits immediately in front. To make the embankments stable very flat slopes have been necessary on the faces of the bank. Such slopes must have a wide base, which, in connection with the borrow pits, necessitates a comparatively wide and therefore expen-

sive right of way.

Levees in this country are generally built with a muck ditch underneath, this ditch being filled with a selected material, to form, to some extent, a sub-core or cut-off wall to prevent water passage through the foundations below the base. The steel sheet piling, as shown in Figures 1 and 2, takes the place of this muck ditch.



A levee containing a face wall of Lackawanna Interlocking Steel Sheet Piling protected by a concrete facing can easily be made proof against the weaknesses mentioned and can to a large extent eliminate the danger and damage caused by breaks during flood periods. Consequently this construction is capable of effecting a great reduction in the annual cost for repairs and maintenance along the more dangerous and exposed stretches of the levee system. The protection, construction advantages and ultimate economy from the steel-faced levee make this construction particularly desirable for long stretches of river where the levee foundations are swampy, the filling material poor or insufficient and the location subject to strong wind and wave action.

The construction advantages and reduction of embankment and right of way, too, are evident from Figure 1, page 71, and the comparison of quantities involved in the construction of a 21-foot levee of each type. Taking all these factors into consideration, the steel-faced levee is by far the more practical and economical, especially in the more dangerous locations.

The advantages of a levee faced with Lackawanna Protected-Steel Piling are evident from

data below. Referring to the embankment details, Figure 2, page 71, the piling is shown as extending to a considerable depth, in this case 16 feet below the base of the levee, or below the original ground surface. Such depth is much greater than the depth of the average muck ditch as built for a levee of this height, so the piling would eliminate the necessity of the muck ditch. The prolongation of the steel below the base of the levee and comparatively deep into the underlying foundation material is very desirable, as an impermeable cut-off wall is formed to prevent the passage of water at these points. Such a wall further assists in retaining soft underlying material against movement due to the weight of the superstructure.

The design shown tends to eliminate the causes of failure, reduces the chance of danger and damage to the levee and the property which it protects, reduces the cost of maintenance and repairs to a minimum and in these ways alone will in time show sufficient savings to warrant the expense for the installation of the steel. This is especially true at points where levees, otherwise constructed, would be continually exposed to dangerous conditions during floods.

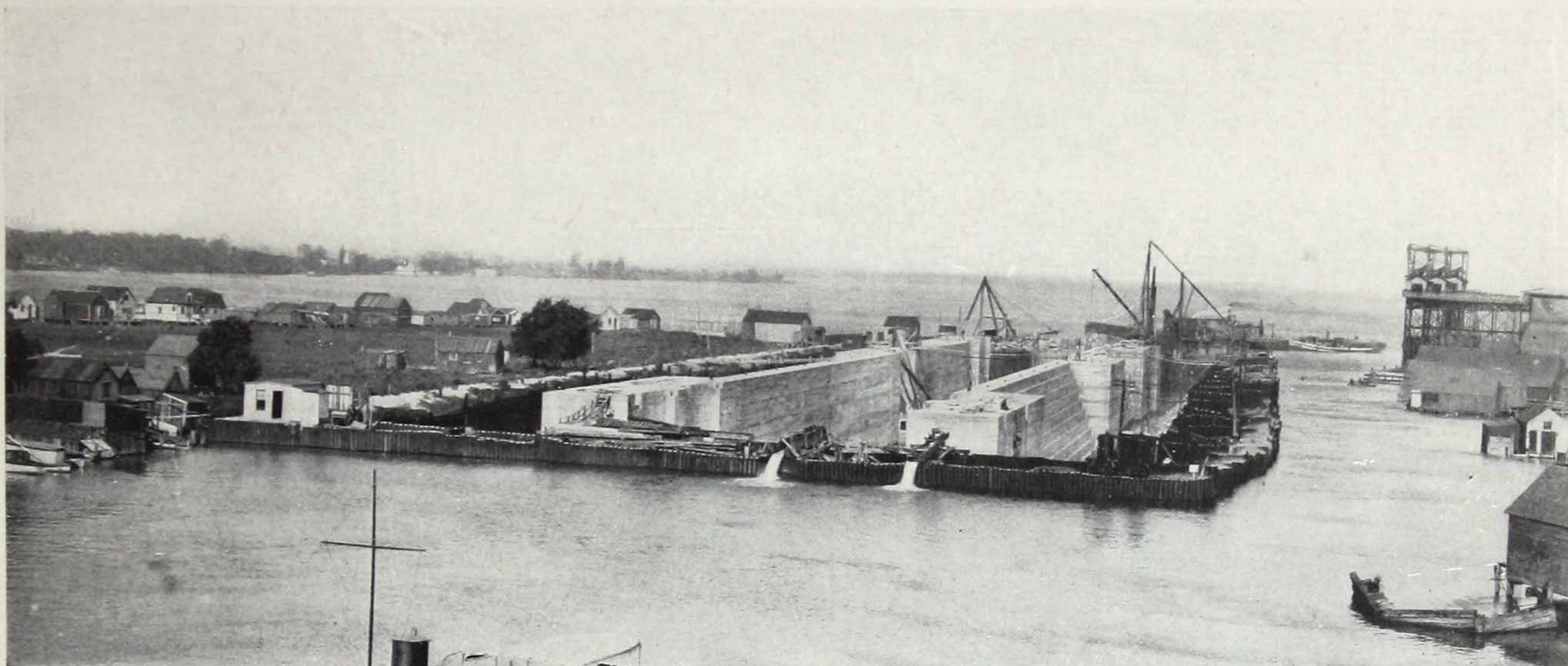
Quantities involved in the construction of a 21-foot levee of standard earthen and steel-faced types

The latter construction is shown to possess decided advantage of space saving in constricted location, through populous territory, and where right of way is for other reasons expensive.

Quantities	Standard earthen levee	Steel-faced levee	Remarks
Width in ft., outer edge of borrow pit to rear of levee	685	214	Steel-faced levee requires only 31.2 per cent of width of right of way required by standard earthen levee.
Right of way, acres per mile	86.67	28.97	Steel-faced levee requires only 33.4 per cent of the right of way acreage required by standard earthen levee.
Earth embankment, cu. yds. per mile	425,823	100,066	Steel-faced levee requires only 23.5 per cent of the yardage required by standard earthen levee including muck ditch.
Earth embankment, cu. yds. per 100 ft.	8,064.8	1,895.2	
Excavation, cu. yds. of muck ditch per 100 ft.	770.4	0	Steel-faced levee does not require a muck ditch.

Lackawanna Steel Sheet Piling

Cofferdam for the Government Ship Lock at Black Rock Harbor



General view of Cofferdam. Concrete walls of ship lock completed.

THE cofferdam in which was built the United States ship lock in Black Rock Harbor, Buffalo, N. Y., was an unbraced steel and puddle structure extending down to bedrock. The Ship Canal for which this lock was built is a Government project, estimated cost \$4,500,000. to take lake vessels around the rapids of the Niagara River, and to the terminus of the New York State Barge Canal at Tonawanda, some miles north of the lock site. The lock overcomes a fall of 5 feet of water between ship canal and Niagara River.

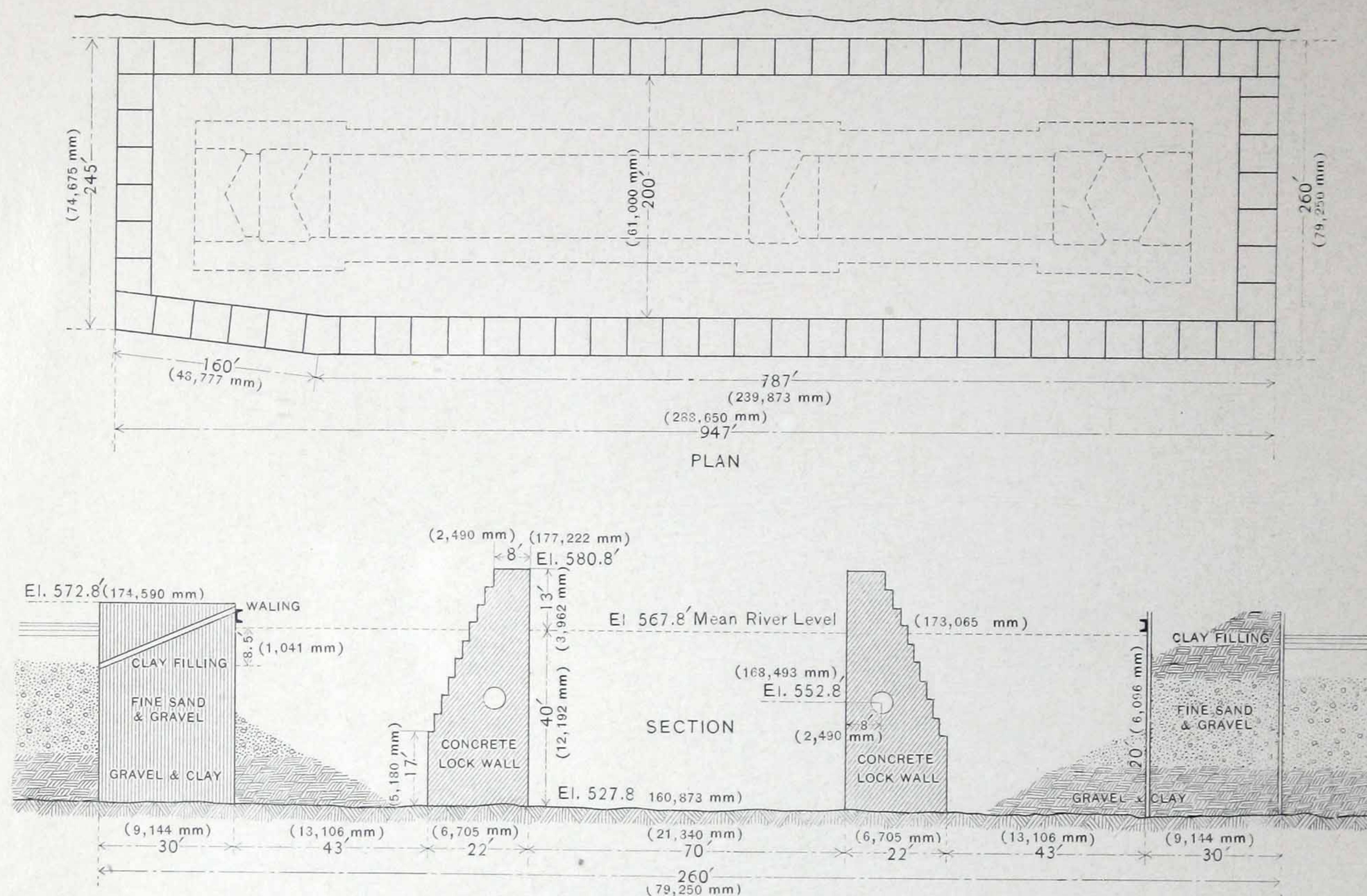
On account of unusually large dimensions and the great pressure head resisted, the cofferdam was the most important and interesting steel sheet piling structure that had ever been built. It was rectangular in plan, 260 feet wide by 947 feet long over all, with walls 30 feet thick and about 45 to 50 feet high, enclosing a 200 by 887-foot space, 43 feet wider on all sides than the permanent walls of the lock. The principal quantities involved in the construction included 6,589 tons of steel sheet piling erected into 6,870 lineal feet of steel sheet piling wall, which is the largest piling construction on record, 192,000 pounds of 15-inch 40-pound channels, 15,000 pounds of bolts and splice plates, 40,000 yards of clay fill, 20,000

yards of clay bank, 175,000 yards of interior excavation and originally about 50,000,000 gallons of inclosed water.

The lock itself is a concrete structure, 817 feet long by 122 feet wide over all, founded on solid rock at a depth of 36 to 45 feet below mean water level. Before the construction of the lock was commenced the water (above the mud) at the site averaged about 8 feet in depth, varying from 1 foot to 15 feet, and had very little current or waves in ordinary weather. The bottom consisted chiefly of fine sand with some earth and gravel and occasional lenses of hard pan directly overlying the rock. Most of the earth overlying the bedrock was a highly saturated material. The surface of the rock is nearly horizontal throughout the length of the cofferdam, but the rock strata has a pitch to the south where the rock is lowest, and there are several ledges that crop out across the lock site.

The Government specifications left the methods of construction of the cofferdam to the contractor, subject to approval of Government engineers, but required double parallel walls of vertical interlocked steel sheet piling, 30 feet apart, connected at intervals of 30 feet by interlocked transverse walls of steel sheet piles, thus forming 77 closed

ISLAND

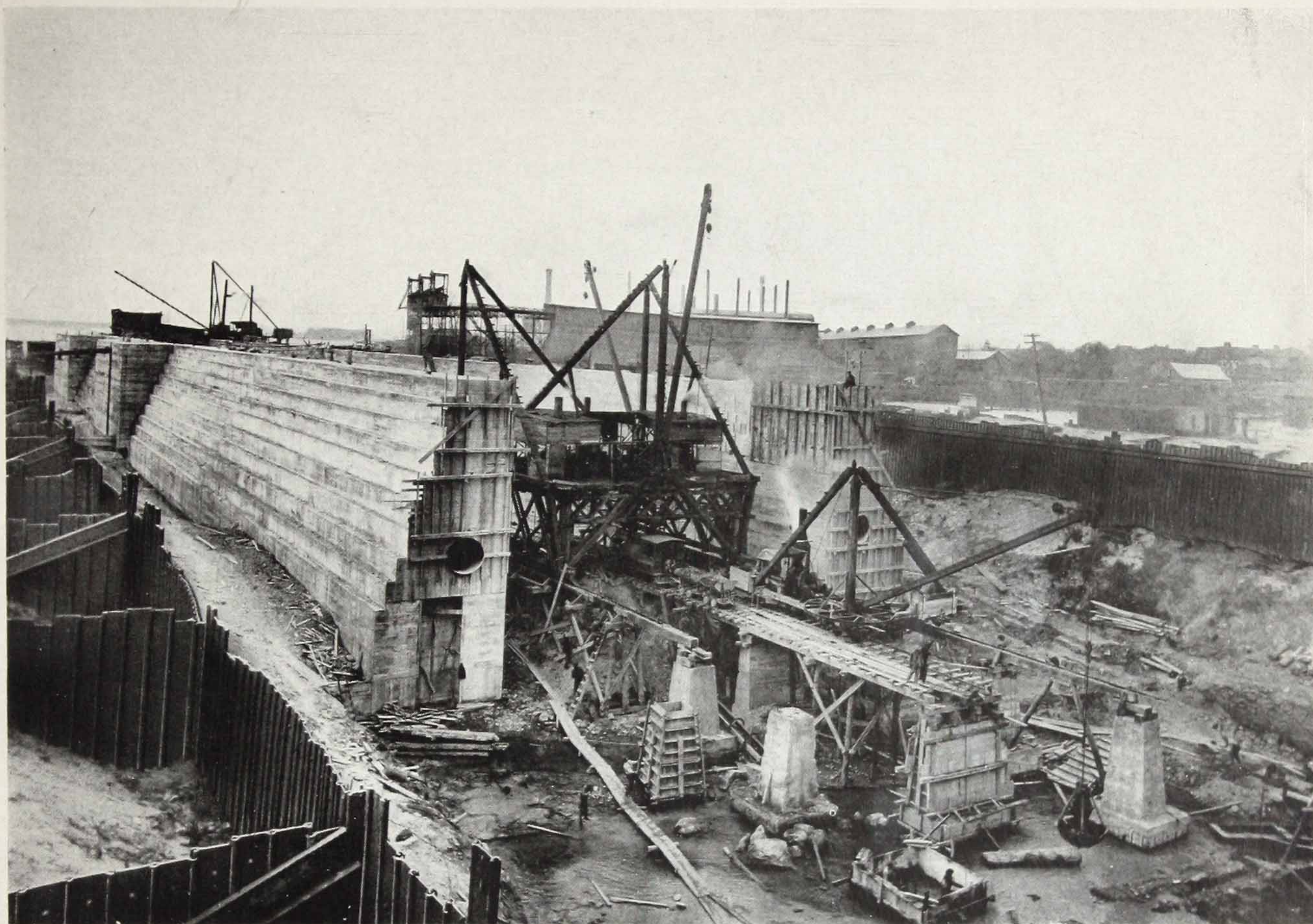


Plan and section of the Cofferdam and ship lock.

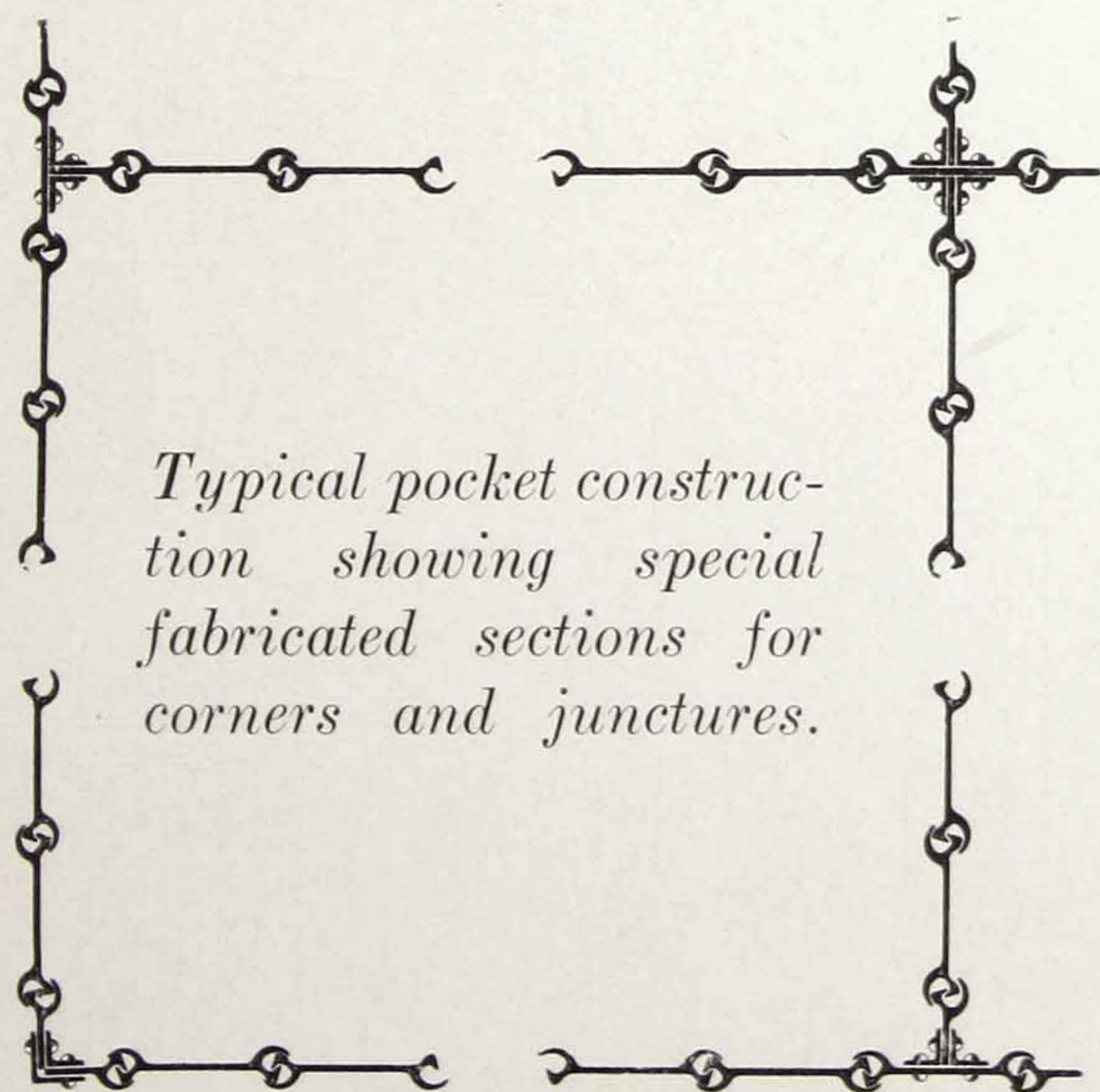
Although the cofferdam stood in water and

There was a great variance in the bids on this work, as was expected, as this was the first large

Lackawanna Steel Sheet Piling



Interior of the Black Rock Cofferdam showing concrete ship lock erected up to the last section.



Typical pocket construction showing special fabricated sections for corners and junctures.

contract where the pulling of steel sheet piling was the initial consideration.

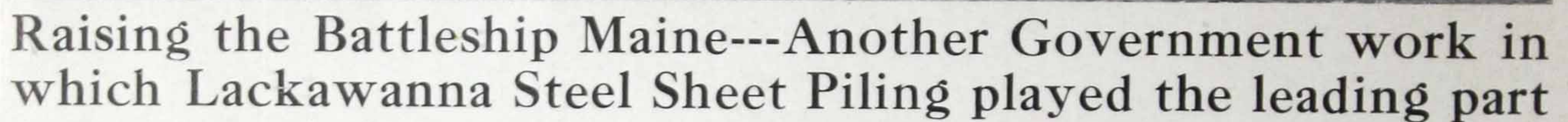
The clay filling was excavated from the pockets

to a depth of 12 feet by a clam-shell derrick dredge, prior to the pulling of the steel sheet piling. Two ordinary floating pile-driver rigs, each having three-sheave steel blocks, with small forged steel pulling grip, were used to pull the steel sheet piling.

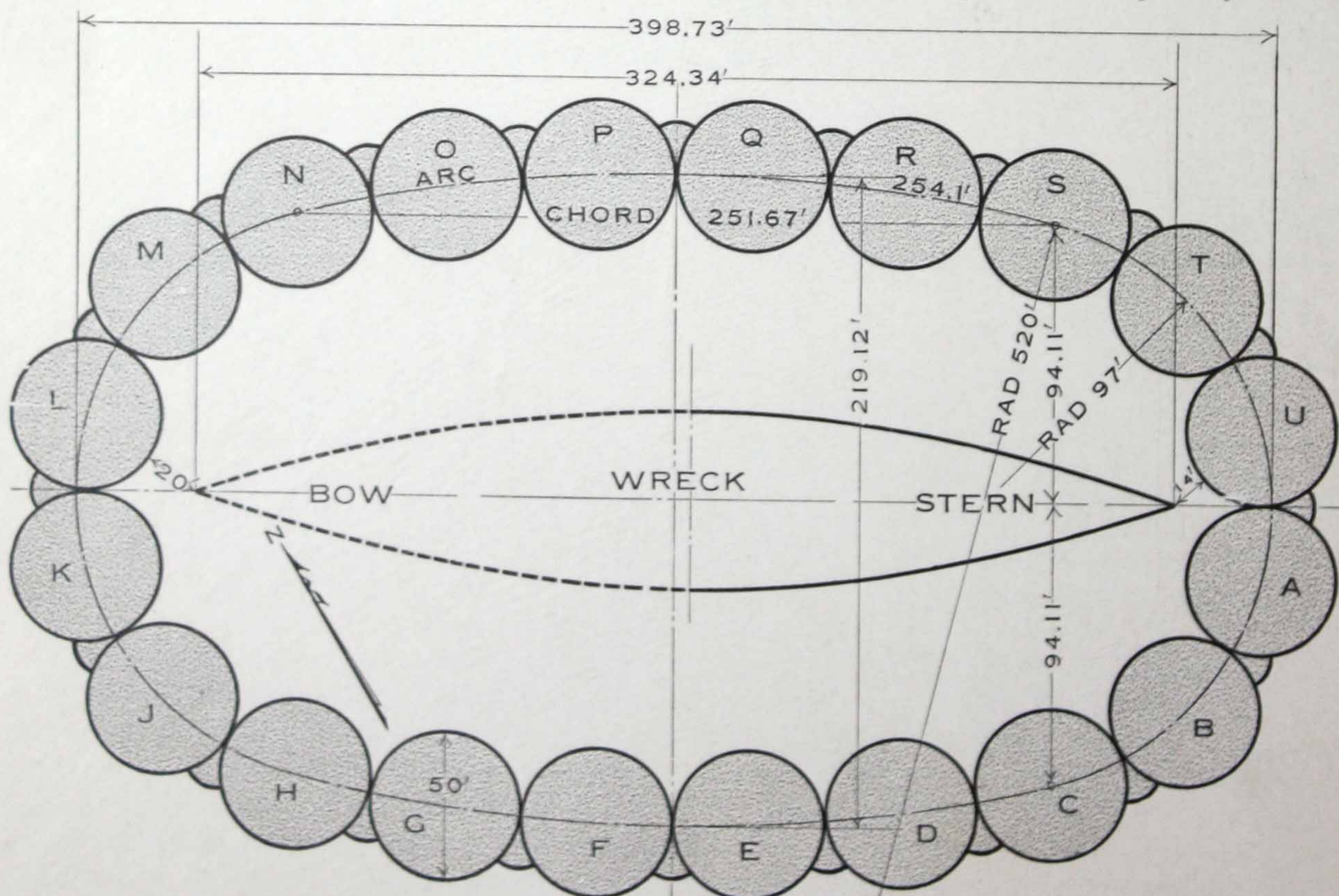
Pile puller No. 39, working 10 hours per working day, from May 6th to October 2nd, extracted 1,989 steel sheet piles.

Pile puller No. 2, working 16 hours per working day, from June 11th to September 21st, and 10 hours per working day, from September 22nd to December 4th, extracted 4,424 steel sheet piles.

The maximum daily record of the number of piles pulled was: August 15th, puller No. 39 extracting 30 piles, puller No. 2 extracting 89 piles, or a total of 119 piles. The maximum daily record of No. 2 rig was 89 piles extracted in 16 hours. The maximum daily record for No. 39 puller was 43 piles in 10 hours.



As shown below, this cofferdam was based upon 20 equal and connected cylinders of Lackawanna Steel Sheet Piling, driven in 75-foot spliced lengths and making an enclosure only large enough to give clearance to parts of the wreck which had been blown beyond the position occupied by the hull.



Lackawanna Steel Sheet Piling

Soundings had indicated that the cofferdam when unwatered would have to withstand pressures from 37-foot head of water in the harbor and from 21 to 23 feet of soft harbor bottom. The inside wall of each cylinder would have to withstand pressures from about 40 feet of soft clay filling within the cylinders, this filling loaded onto original soft harbor bottom. The units of the cofferdam were made cylindrical so that the extremely high pressures exerted by the mud filling would act radially and uniformly on each pile, straining each interlocked piling joint to equal amount at equal depths, and in the entire cofferdam cylinders would deform least from play in the piling interlocks.

It is obvious that the highest obtainable ultimate joint strength must be one of the properties of the steel sheet piling chosen. We guaranteed

to the Maine Board that Lackawanna Steel Sheet Piling would develop an ultimate tensile strength of 9700 pounds per lineal inch of interlock. This guarantee was based upon a series of 48 tests, in only two of which the ultimate strength was below 10,000 pounds. Other tests ranged up to 16,000 pounds and the average was 11,975 pounds. No authoritative figures proving such a high joint strength have ever been offered by any other piling manufacturer.

With the known excellence of Lackawanna Steel Sheet Piling for easy driving, the government engineers were therefore justified in using Lackawanna Piling exclusively. Other features of the work on the Maine are described in our Bulletin No. 102, which will be sent upon application. Contractors will be well repaid by reading carefully about this most important job.



The Maine floated and tied outside the cofferdam and ready for the final voyage.



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